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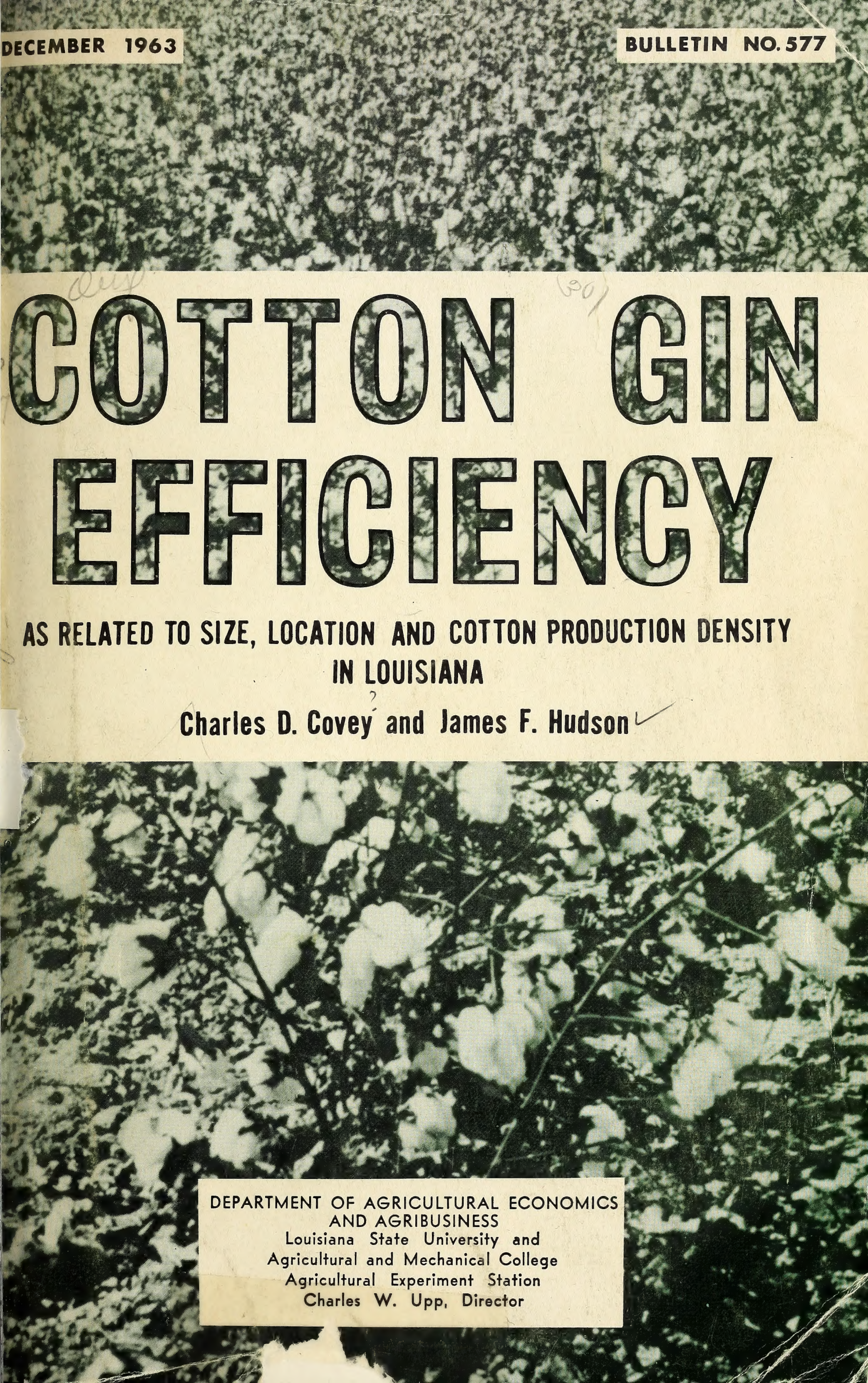

COTTON GIN EFFICIENCY

AS RELATED TO SIZE, LOCATION AND COTTON PRODUCTION DENSITY IN LOUISIANA

Charles D. Covey and James F. Hudson

DEPARTMENT OF AGRICULTURAL ECONOMICS
AND AGRIBUSINESS
Louisiana State University and
Agricultural and Mechanical College
Agricultural Experiment Station
Charles W. Upp, Director

FOREWORD

Changes in cotton production and harvesting practices within recent years present a serious economic problem to ginners. Many ginners are faced with the decision of updating gin plants or losing customers to more modern gins. Such decisions must inevitably consider various investment alternatives, the potential volume of cotton available and factors involved in extending the gin service area. This report presents the results of a study of the costs of assembling and ginning cotton in Louisiana. It is intended to serve as a guide to ginners and others interested in these problems. The report is divided in a manner which, it is hoped, will make it more useful and understandable to those who read it. The discussion from pages 5 to 62 contains the general findings of the study.

Appendix A is written with the professional economist and researcher in mind and is concerned with methodology and the technical aspects of model construction.

John S. Roussel
Coordinator
Cotton Research

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COTTON GIN EFFICIENCY

As Related to Size, Location and Cotton Production Density in Louisiana

By Charles D. Covey *and* James F. Hudson[1]

INTRODUCTION

One of the major agricultural or agribusiness problems in Louisiana and the Cotton Belt is the presence of many cotton gins which do not command sufficient volume to justify investment in the equipment necessary to produce quality lint. New machine harvesting techniques and rougher hand picking practices require more cleaning and conditioning facilities in the gin. These new harvesting techniques have generally resulted in a shorter, more timely harvesting season. This, in turn, has produced a situation in which the receipt of seed cotton, at times, far exceeds existing gin capacity even though gin capacity is generally considered as excessive.

Because of the irregular distribution of seed cotton receipts, ginners are faced with an inconsistent economic planning horizon. On the one hand, cotton acreage and production have generally been decreasing in the state since the early 1930's. For the most part, ginners have little reason to believe that this trend will not continue. On the other hand, the demand for ginning services at certain times of the year often exceeds existing gin capacity. Moreover, the continuing trend away from hand harvesting and one-row mechanical pickers promises to intensify this problem even more. These apparently contradictory trends pose serious problems for the ginner who wants to meet the demand for ginning services in his area.

The declining number of cotton gins in Louisiana and other cotton producing states of the South probably is the twofold result of decreasing cotton acreage and production, and the increased equipment investment needed to provide quality lint from rough harvested cotton.

The number of cotton gins in Louisiana has continued to decline since 1915. In 1915 a total of 1,086 cotton gins in Louisiana ginned approximately 336 thousand bales of cotton. In 1961 a total of 226 active gins in the state ginned about 479 thousand bales of cotton. This is a 79 percent reduction in gin numbers, with the amount of cotton ginned increasing by about 43 percent. The average volume per gin amounted to about 2,119 bales for the 1961-62 season.

A modern, high-speed gin of only moderate size is capable of ginning far more than the 1961-62 average volume per gin in Louisiana. For example, a modern high-speed gin with an 8-bale-per-hour capacity can gin in excess of 11 thousand bales annually. Consequently, it would appear that many gins in the state are either not operating at capacity or are older gins with relatively small capacity. Many of these outdated gins have been and are operating at outputs of 100 to 500 bales per year.

---

[1] Former Instructor and Associate Professor, respectively, Department of Agricultural Economics and Agribusiness, Louisiana State University.

In trying to cope with the problem of insufficient gin volume, ginners are often confronted with long-run economic prospects which are not conducive to investment in additional gin capacity.[2] This is particularly true in Louisiana, where cotton acreage has been declining since 1930. This problem is even more pronounced in some sections of Louisiana where the decrease in production relative to the decrease in acreage has been greater than in other parts of the state.

Assuming cotton remains a major agricultural crop in certain sections of Louisiana, there will be a continuing need for a ginning industry capable of turning out quality lint at costs which reflect a high degree of efficiency. Ginners planning to make the capital investment necessary to provide this vital service will need certain guides relative to economies of scale in gins, assembly costs, and locational factors.

Purpose of the Study

The fact that lower per bale ginning costs are associated with increased volumes of cotton ginned is well documented in the literature concerning cotton gins.[3] The achievement of these economies is dependent upon the availability of sufficient cotton in the vicinity of the gin. This study will be concerned primarily with examining those problems of combining assembly costs of cotton with costs within the gin to achieve least-cost combinations.

Increasing the volume of a commodity at any processing plant involves either increasing the production density in the existing supply area or expanding the present supply area. Both alternatives ordinarily will involve increased costs. If production density is increased in the existing supply area, the price of some important productive factors will be bid up. If the supply area is enlarged, unit hauling costs will increase with the increased length of haul. In addition, if the supply area expansion overlaps the supply area of a competitive processing plant, the commodity price will be bid up. In the case of cotton ginning, since the ginner performs a service and does not ordinarily take title to the commodity, attracting additional volume away from a competitor would involve a reduction in ginning charges or providing additional services at no added cost to the customer. At present there appears to be very little price competition among Louisiana ginners, although considerable evidence of non-price competition is present.

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[2] As used in this study, volume is defined to mean the amount of cotton which the gin actually gins during a given period. Capacity, as used herein, refers to the total amount of cotton which the gin is capable of ginning during a given time period. The annual and hourly capacity of model gins will be defined more precisely in the section on model gin costs.

[3] For a relatively complete listing of these studies, see C. D. Covey, "Cotton Gin Efficiency as Related to Size, Location and Cotton Production Density in Louisiana" (Unpublished Ph.D. dissertation, Department of Agricultural Economics and Agribusiness, Louisiana State University, 1963).

Because cotton is produced under relatively rigid acreage controls which attach the allotment to the land and because of well-defined patterns of technological adoption, the first alternative of increasing production density in the existing supply area is of limited use. The second alternative, expanding the supply area, appears to be a feasible method of increasing the supply of seed cotton available to cotton gins.

The problems of cotton ginners are somewhat different from those of processors ordinarily considered in the literature. Most studies heretofore have dealt with assembly costs and in-plant economies of scale for processing operations where the processor has taken title to the commodity, usually at the farm. As a result, the processor has felt compelled to consider the total cost structure, which includes both assembly and processing costs. Cotton ginners, on the other hand, ordinarily perform a service for the producer which makes his product suitable to enter existing marketing channels. As a rule, the ginner receives a fee for performing the ginning service, and does not take title to the cotton. As a result, ginners seldom consider the total cost picture of assembly and ginning, although recent moves by ginners to provide trailers for use by customers have made them more cognizant of assembly costs than before.

Although assembly costs are usually borne by the producer and are a matter of indifference to the ginner, this study is concerned with the cost to the industry as a guide to over-all industry objectives.

Decreasing gin numbers and increasing gin capacities indicate a transition in Louisiana from small, simple gins to large, high-speed, elaborately equipped gins. Assuming the continuation of this trend, a long-run economic guide should be helpful to ginners in determining where to locate cotton gins and how large to build them for maximum efficiency.

The ginning and warehousing industry which eventually evolves in Louisiana will largely be determined by certain strategic economic factors. Some of these factors will be examined in this study in an effort to give ginners reliable guides for planning purposes.

The specific objectives of the study are as follows:

1. To develop estimates of seed cotton assembly costs for the most prevalent method of moving seed cotton in Louisiana.
2. To develop estimates of investment costs and operating costs for a relatively complete range of gin sizes for different volumes ginned.
3. To evaluate the influence of cotton production density, assembly costs, length of ginning season, and seed cotton storage on optimum size and location of cotton gins.
4. To demonstrate the application of the results to a selected area of Louisiana.

Method of the Study

The economic framework within which the efficiency of the Louisiana ginning complex will be examined will be one of first demonstrating as nearly as possible the perfect gin complex in the manner postulated by Shepherd for analyzing marketing problems.[4] With this approach it becomes possible to utilize the perfect model as a benchmark for making comparisons with the existing gin complex in Louisiana. It would be unrealistic to expect the perfect model to ever fit actual conditions. However, the perfect model does serve a useful purpose by providing a means of determining the degree of departure from some definable norm or, stated in another way, the degree of inefficiency of the existing system.

Theoretically the perfect gin setup would be one utilizing a supply area, gin size, and gin location which resulted in minimum cost to gin a bale of cotton. The economic framework assumed would be one minimizing the overlapping of gin services which is so common in the existing system.

Considered in isolation, gin size and volume are sufficient to determine least costs of ginning cotton. However, when two stages in the marketing process are combined, as assumed in this study, it is necessary to consider costs for both stages to arrive at a least-cost volume for the combined operation. In the case at hand, the simplest method is to add the two costs together to find a common average per unit cost for the combined process.

In this study a modified economic-engineering approach was used in making estimates of gin cost data. The economic-engineering method ordinarily builds or synthesizes model gins on paper, using manufacturer's and engineer's estimates of equipment capacity, power requirements, labor requirements, equipment costs, installation costs, etc. As an alternative to this method, the method adopted in this study was to conduct a detailed cost analysis of four new, electric cotton gins erected in the state during 1961 and 1962. Fortunately, the sizes of these new gins, measured in bales per hour, fit the needs of this study quite well. The rated capacities of these four gins were approximately 4, 8, 12, and 15 bales per hour. The cooperation of all four ginners was obtained, and investment and operating cost data were collected for the 1961-62 and 1962-63 seasons for the 8- and 12-bale gins and for the 1962-63 season for the 4- and 15-bale gins.

In using a modified economic-engineering approach to model building, individual cost items of the four gins involved have been analyzed carefully and where they do not appear reasonable, adjustments have been made with the help of gin engineers, gin manufacturers, and data from previous gin cost studies. The adjusted gin costs used in this study are judged to be reasonable for new cotton gins operating under Louisiana conditions. These costs may or may not represent average ginning costs for Louisiana, since they are the newest gins in the state out of a total of 226 active gins in 1961.

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[4] Geoffrey S. Shepherd, *Marketing Farm Products-Economic Analysis* (3rd ed.; Ames, Iowa: The Iowa State College Press, 1955), pp. 3-30.

As a source of supporting information, cost data were also obtained from 12 relatively new gins with capacities as nearly equal to those of the new gins as possible. Some difficulty was encountered in obtaining comparable data for the small (4-bale) gin and the large (15-bale) gin.

Cost data relative to transporting seed cotton from the field to the gin were obtained by personal interview with a small judgment sample of cotton producers and custom cotton harvesters. Respondents were selected from lists supplied by county agents in two major cotton producing parishes, Richland and Franklin. Average assembly costs were determined from these data.

In order to demonstrate the divergent prospects faced by ginners in Louisiana with respect to investment planning, two currently important cotton producing areas in Louisiana were selected for study (see Figure 1). Area I, comprising eight Mississippi Delta and Macon Ridge parishes,

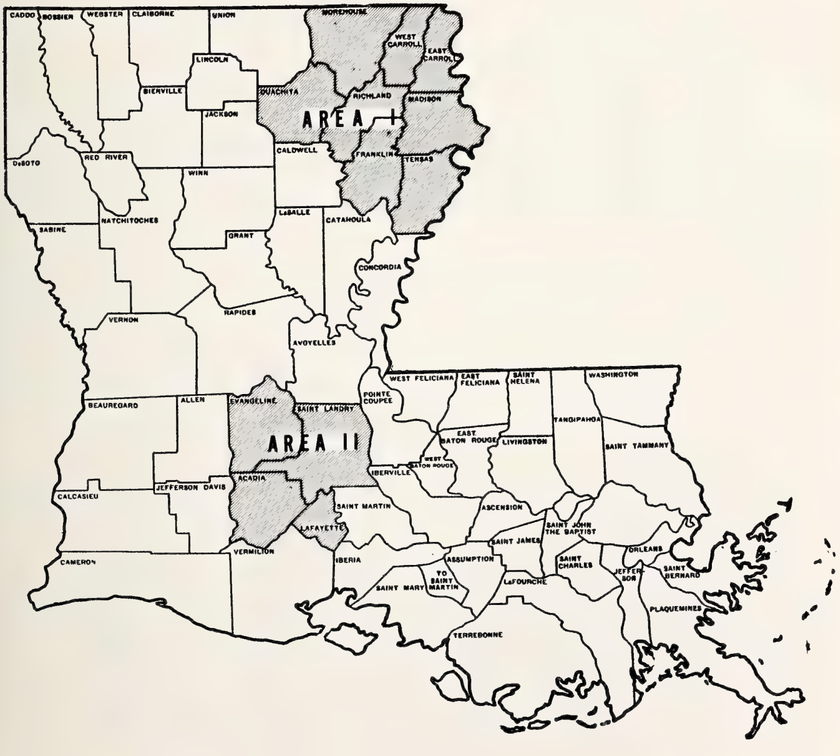

FIGURE 1.—Cotton Production Areas Selected for Study, Louisiana, 1961-62.

TABLE 1.—Cotton Production and Acres Harvested, Selected Louisiana Parishes, 1951-60

Year	Area I[a]		Area II[b]	
	Acres harvested	Bales	Acres harvested	Bales
	Thousand	*Thousand*	*Thousand*	*Thousand*
1951	342	267	135	133
1952	353	275	130	110
1953	415	379	124	79
1954	274	216	94	106
1955	249	254	85	83
1956	236	256	82	100
1957	201	174	70	40
1958	173	140	55	48
1959	227	235	71	58
1960	237	238	72	66

[a] East Caroll, Franklin, Madison, Morehouse, Ouachita, Richland, Tensas, West Carroll.

[b] Acadia, Evangeline, Lafayette, St. Landry.

Source: *Louisiana Cotton: Acreage, Yield, and Production, 1951-60,* Louisiana Crop Reporting Service, Alexandria, Louisiana.

was selected as representative of a cotton production area which was expected to maintain its competitive position as well or better than any other area of the state. By way of a contrast, Area II, comprising four south central parishes, was selected as representative of an area where cotton production is declining in importance. The selection of these two areas was based on a number of factors. Of primary importance was the total cotton acreage, the relative decline in acreage, and the percent of underplanting.

Ten-year averages of cotton acreage and production in these two areas indicate that in Area II harvested acres have been decreasing an average of about 8,480 acres per year over the period 1951-60, while production in bales has been decreasing at about 7,900 bales per year (see Table 1). Increases in productivity per acre have offset about 7 percent of the reduction in acreage. In contrast, the harvested acres in Area I have been decreasing an average of about 19,800 acres per year, while the production per year has been declining by about 11,270 bales. In this area 43 percent of the reduction in acreage has been offset by increased productivity. This compares with 7 percent in Area II.

Other differences which probably would affect gin investment prospects exist between these two areas. While quite subtle, some differences in percentage of total parish allotment planted can be observed in Table 2. These differences appear to have a direct relationship with the average size of allotments in the parish (see Table 3). This is further substantiated by Table 4, which indicates that smaller allotment holders tend to underplant their allotments more than larger allotment holders.

The usefulness of distinguishing between these two areas will be

TABLE 2.—Acreage of Cotton Planted as a Percentage of Parish Cotton Allotments, by Parish, Louisiana, 1955-60

Parish	1955	1956	1957	1958	1959	1960
	Percent					
Area I						
East Carroll	100	100	99	98	97	98
Franklin	100	100	99	97	94	98
Madison	99	99	98	98	97	98
Morehouse	100	100	98	97	95	98
Ouachita	98	98	95	89	94	96
Richland	100	99	99	97	93	95
Tensas	100	100	98	97	95	96
West Carroll	98	99	97	94	90	96
Area II						
Acadia	96	95	94	92	75	85
Evangeline	98	98	96	95	84	89
Lafayette	96	96	90	88	73	79
St. Landry	99	99	95	96	89	91

Source: U.S.D.A., Louisiana Agricultural Stabilization and Conservation Committee, *Report of Programs*: *1959-60,* Alexandria, La.

TABLE 3.—Average Size Cotton Allotments, by Parish, Louisiana, 1960

Parish	Acres
Area I	
East Carroll	35.3
Franklin	26.4
Madison	30.4
Morehouse	29.2
Ouachita	23.0
Richland	28.5
Tensas	32.0
West Carroll	14.7
AVERAGE	25.9
Area II	
Acadia	9.9
Evangeline	10.3
Lafayette	7.9
St. Landry	10.1
AVERAGE	9.6

Source: Computed from: U.S.D.A., Louisiana Agricultural Stabilization and Conservation Committee, *Report of Programs*: *1959-60,* Alexandria, Louisiana, pp. 58-59.

TABLE 4.—Percentage of Allotment Planted, by Size Distribution of Allotments, Louisiana, 1960

Allotment size	Allotment acreage planted
Acres	*Percent*
0.1- 10.0	64.9
10.1- 29.9	87.5
30.0- 49.9	89.4
50.0- 74.9	91.2
75.0- 99.9	93.4
100.0-199.9	97.0
200.0-299.9	97.2
300.0-399.9	97.7
400.0-499.9	98.7
500.0-799.9	99.1
800.0 or more	98.5

Source: U.S.D.A., Louisiana Agricultural Stabilization and Conservation Committee, *Report of Programs: 1959-60,* Alexandria, Louisiana, p. 57.

evident when the different cotton production prospects for these areas are reflected in the investment outlook for model gins in terms of expected future cotton receipts and debt amortization.

Limitations of the Study

To those who might use the results of this study without a full appreciation of the methodology used, a word of caution seems appropriate. The fixed cost allocations and some of the assumptions used in the study were necessarily based on judgment. However, the cost estimates used are considered to be typical and reasonable for the situations in which they occur. When an assumption was made which required a considerable amount of judgment, because of a lack of information or because of wide divergences in available information, a special effort was made to spell-out the decision in detail in order that the reader might reach his own conclusions concerning its validity. No apologies are made for this exercise of judgment since the synthetic approach to the generation of cost data, by its very nature, requires such action.

A further limitation of the study involves the distribution of seed cotton receipts at gins. The distribution used was a 10-year average and masked the wide differences in harvesting patterns which occur from year to year. This distribution was basic to the determination of annual gin capacities and to the costs involved in the storage of seed cotton. To the extent that year to year changes in the distribution of seed cotton arrivals differ from the average distribution used, annual gin capacities and the amount of seed cotton requiring storage will depart from those used in this study.

ASSEMBLY COSTS OF SEED COTTON

Most early studies of cotton ginning costs considered only those costs within the gin itself. Almost without exception the conclusion drawn by such studies was that the key to more efficient ginning and lower costs was added volume. The relatively high fixed costs per unit of output, coupled with the constant speed characteristic of cotton gins, account in large measure for this conclusion.

Previous studies appear to be correct in the conclusion that volume is the key to increased efficiency and lower ginning costs; however, they go no further than the recommendation that gins should increase their volume. The added costs of assembling this volume have been vaguely alluded to in only one or two studies.

Additional cotton can be obtained at the gin by increasing the intensity of production in the existing supply area, extending the supply area, or a combination of both. In either event, added costs are incurred to obtain the additional volume. More intense production within the existing supply area will bid up the price of certain input factors, while extending the supply area will increase per unit costs of assembly.

Because of the acreage controls now imposed on cotton production, the alternative of more intense production in the existing supply area is of limited use. It is possible, of course, with the adoption of presently known technology to increase production in a given plot or allotment by a substantial amount, but innovations and new techniques are ordinarily adopted by producers in a rather well defined pattern. That is, the number of farmers adopting a particular new practice over time will closely approach a normal or bell-shaped distribution.[5] For this reason, it does not appear reasonable to assume there will be an appreciable acceleration in the adoption of new cotton production technology, and consequently the alternative of more intense production in the supply area is of limited usefulness.

In light of the limitations placed on production by the acreage control program and the current surplus position of cotton, the alternative of extending the supply area appears to be the most fruitful approach to increased volumes at cotton gins.

Any manageable approach to the determination of seed cotton assembly costs must of necessity involve a number of simplifying assumptions. The principal assumption made in this analysis is that all facilities necessary to move seed cotton to gins already exist and are sufficient to handle the applicable volumes of cotton. Within some, as yet undefined, distance from the gin this assumption conforms to actual conditions. However, at some point, when time consumed in hauling from more distant points makes it necessary to invest in additional hauling equipment, this assumption becomes less realistic. Within the framework of the existing gin complex this assumption would break down quicker than in a situation where some type of seed cotton storage was available at cotton gins. Storage facilities would permit farmers to unload their trailers upon arrival at the gin and return almost immediately to the field, thereby obtaining a more efficient utilization of trailers. The limiting factor under existing conditions is the time which is utilized by the loaded trailer sitting on the gin yard waiting to be emptied. When compared with waiting periods at the gin of 12, 24, and even 36 hours, the actual road time for trailers is relatively insignificant even from the more distant points of production. For example, ginners in Louisiana indicate that relatively little cotton is hauled more than 10 miles to be ginned. At 25 miles per hour this is approximately 48 minutes road time, both ways.

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[5] Everett M. Rogers, "Categorizing the Adopters of Agricultural Practices," *Rural Sociology*, XXIII, 1958, pp. 345-354.

Method of Assembly

In Louisiana, cotton is brought to the gin in almost any conceivable type of vehicle, from a mule and wagon hauling 1 bale to large four-wheel trailers hauling 10 or more bales. Five-bale, four-wheel trailers are quite common and are the usual size supplied to farmers by cotton gins. Use of an empty pickup truck for motive power allows the farmer to leave the loaded trailer at the gin and immediately return to the field with an empty trailer, if available.

Ordinarily one pickup truck will serve as the motive power for a number of cotton trailers. The exact ratio of pickup trucks to trailers would depend on a host of factors, including such things as number of trailers owned, number of pickers operated, distance from the gin, and size of the trailers. The ratio of trucks to trailers is given consideration in the cost estimates by spreading fixed costs over considerably more miles of travel for the truck than for the trailers during harvesting season. A pickup truck is used for numerous jobs associated with harvesting other than pulling seed cotton trailers. Actual road time pulling trailers to and from the gin appears to be quite small relative to the amount of time spent at the field end of the trip performing service tasks. Ordinarily the truck is tied up at the gin end of the trip only long enough for the driver to unhook, locate an empty trailer and hook on to it.

Estimates of costs associated with the use of pickup trucks and cotton trailers used to haul cotton from the field to the gin were obtained from several sources. Data on truck prices, average years of use, and average trade-in values were obtained from several truck dealers. Cotton trailer prices and estimates of useful life were obtained from a small, judgment sample of cotton producers and custom cotton harvesters. The sample was drawn from lists of producers and custom harvesters supplied by the county agents in two major cotton producing parishes. Each respondent was interviewed and cost and related data obtained on his operation relative to moving seed cotton from the field to the gin.

Truck Costs

The harvesting and hauling of seed cotton is a seasonal operation, with producers using their pickup trucks for other enterprises throughout the remainder of the year. Fixed costs associated with the truck must be allocated between these various enterprises. The general consensus among those producers interviewed was that about one-third of the truck costs should be allocated to seed cotton harvesting and hauling.

Fixed Costs

Prices of pickup trucks ranged from $2,800 to $1,600. In addition, there was a wide divergence of opinion as to the size of pickup most suited to cotton hauling. Some producers found ½ ton trucks adequate, while others considered ¾ ton trucks best. In those operations where the truck was used to pull loaded trailers out of the field, ¾ ton trucks were found most satisfactory. Other producers kept a tractor in the field to pull trailers out to the road. In this case, ½ ton trucks were considered adequate. The average replacement cost of all estimates was $2,200. This figure was used in computing interest and depreciation costs.

TABLE 5.—Estimated Annual Fixed Costs of Operating ½ - ¾ Ton Pickup Trucks, Louisiana, 1961-62

Item	Average annual fixed cost
	Dollars
Depreciation:	
Straight line, 5 years, with $500 trade-in allowance[a]	340.00
Insurance:[b]	
(a) Public liability ($10,000 - $20,000)	28.60
(b) Property damage ($5,000)	13.00
(c) Comprehensive (Fire, theft, and windstorm)	19.40
(d) Collision ($100 deductible)	87.40
Interest on investment:[c]	66.00
State license tags:	3.00
Annual state vehicle inspection	2.00
Total annual fixed costs	559.40
Per mile fixed costs[d]	0.047

[a] $D = \frac{C-S}{N} = \frac{2{,}200 - 500}{5}$ where:

D = Annual depreciation
C = Replacement cost
S = Trade-in allowance
N = Number of years used.

[b] Obtained from Louisiana State Insurance Commission, Rating Bureau, Baton Rouge, Louisiana.

[c] $I = \frac{C}{2}(r)$ where:

I = Average annual interest cost
C = Replacement cost = $2,200
r = Current average rate of interest = 6%.

[d] Truck operated 12,000 miles per year.

In estimating per mile truck costs of hauling seed cotton an assumption concerning the annual truck mileage was necessary. Based on the limited information available it was assumed that the truck was driven 12,000 miles each year. Per mile fixed costs were determined by dividing the total costs by the total miles driven each year.

Fixed costs associated with the use of a pickup truck include depreciation, interest on investment, insurance, taxes, and inspection fees (see Table 5).

Variable Costs

The variable costs or operating costs per mile include such cost items as fuel, oil and filters, lubrication, tires, and repairs and maintenance (see Table 6).

TABLE 6.—Estimated Variable Costs of Operating ½ - ¾ Ton Pickup Trucks, Louisiana, 1961-62

Item	Average cost per mile
	Dollars
Gasoline (10 M.P.G. @ 30c per gallon)	0.030
Oil (6 qts. per 1,000 miles @ 40c per qt.)	0.002
Filter (1 per 1,000 miles @ $2.00)	0.002
Lubrication (every 1,000 miles @ $1.50 ea.)	0.001
Tires ($125.00 per set of 4, 18,000 miles per set)	0.007
Repairs and maintenance ($64.89 per year, 12,000 miles per year)	0.005
Total variable cost per mile	0.047

Fuel and Lubricants — Estimates of gasoline consumption for pickup trucks averaged about 10 miles per gallon. Gasoline costs were figured at 30¢ per gallon. Nearly all truck owners interviewed indicated that they changed the oil and filter in their trucks every 1,000 miles. Some indicated they bought oil in bulk and changed it themselves, and others said they had it changed at a service station. Prices of oil ranged from 33¢ a quart in the bulk to 60¢ a quart at service stations. An average of 40¢ per quart was used to compute oil costs.

Truck owners also said they lubricated their trucks every 1,000 miles. The cost of a lubrication job was figured at $1.50.

Tires — Truck owners reported considerable variation in tire costs. Those producers who had limited farming operations reported lower annual tire costs than truck owners engaged in large farming operations or in custom harvesting work. While annual tire costs did vary considerably among truck operators, the variation was somewhat less when figured on a per mile basis. Based on the limited information available, 18,000 miles was selected as a reasonable estimate of the mileage obtained from a set of pickup truck tires. None of the producers interviewed indicated they used recapped tires on their trucks.

Repairs and Maintenance — Repairs and maintenance varied considerably with the age of the truck and the type of enterprises engaged in by the truck owner. On the average, maintenance and repairs amounted to $64.89 per year on each truck. In order to compute a per mile estimate for maintenance and repairs it was assumed that each truck averaged about 12,000 miles each year.

Labor – Producers generally agreed that road speeds in excess of 25 miles per hour with a loaded cotton trailer were not practical. Beyond this speed cotton begins to blow off the load if not covered. None of the producers interviewed said they covered cotton trailers while in transit. Therefore, labor costs for road time were figured at 25 miles per hour both ways.

Ordinarily the owner drove the truck in hauling cotton to the gin. Most producers, however, felt that suitable labor could be obtained to perform this function for $1.00 per hour.

The time per trip, or the time per 5 bales hauled, assuming a 5-bale-size trailer, is made up of an independent fixed part and a variable part which is a function of distance. The fixed labor cost per trip is dependent upon the time spent at the field end of the trip, and the time spent at the gin. Estimates of the time spent at the gin indicated considerable uniformity and averaged about 20 minutes per trip, or just long enough to unhook a loaded trailer and find and hook-up an empty one. Within the limits of the assumptions made in this study, 20 minutes appears to be a reasonable estimate of time spent at the gin.

Reliable estimates of the time spent at the field end of the trip were extremely difficult to obtain. The primary reason for this was the fact that owners were serving as truck drivers and managers at the same time. Consequently, the driver might be called upon to perform any number of different tasks in the field, from tramping cotton to repairing or greasing the cotton picker. In light of the limited information available a somewhat arbitrary estimate of 2 hours was used. Estimates of both fixed and variable labor costs associated with the assembly of cotton are shown in Table 7.

TABLE 7.—Estimated Fixed and Variable Labor Costs for Hauling Seed Cotton by Pickup Truck and Four-Wheel Trailer, Louisiana, 1961-62

Item	Cost
	Dollars
Variable labor costs:	
Time on road (25 M.P.H. @ $1.00 per hour)	0.04 per mi.
Fixed labor costs:	
Time in field (2 hours @ $1.00 per hour)	2.00 per trip
Time at gin (20 minutes @ $1.00 per hour)	0.33 per trip
Total fixed labor costs per trip	2.33

Trailer Costs

Investment and operating cost estimates were obtained on four-wheel, steel cotton trailers with a capacity of approximately 5 bales of spindle-picked cotton. While those producers interviewed used various size four-wheel trailers, all of them had one or more 5-bale trailers and most indicated they planned to buy this size in the future.

Fixed Costs

Fixed costs for cotton trailers include only two items, depreciation and interest on investment. No costs were included for insurance, license tags, or state vehicle inspection. None of the producers interviewed carried any type of insurance on cotton trailers. Most stated, however, that their truck liability and property damage coverage also included the trailer. No license tags or inspection fees are required on farm trailers in Louisiana.

Depreciation – Estimates of the usable life of a steel cotton trailer ranged from 10 to 15 years. Most producers reported that the life of a steel trailer would be considerably less if it was not painted regularly or kept under cover. None of the producers interviewed reported any investment costs in trailer sheds. By using a 12-year depreciation period and not including a cost for shelter, it was necessary to include the cost of painting the trailer every three years. Essentially, the cost of preserving the trailer from weather damage is included as a variable rather than a fixed cost.

Very few cotton producers indicated that they used their cotton trailers in other farming enterprises. Most were of the opinion that all depreciation and interest should be charged to the cotton harvesting operation.

Depreciation costs on trailers were computed in the same manner as for pickup trucks except that the useful life was extended to 12 years and no salvage value was assigned.

Interest on Investment – The average annual interest on investment costs for trailers was computed in the same manner as for trucks; the replacement value was divided by 2 and multiplied by the current rate of interest.

Variable Costs

Although a distinction has been made between fixed and variable costs associated with the use of cotton trailers, the distinction is not clear. It could be argued that all costs are fixed in nature. Tires, for example, deteriorate whether the trailer is used or not. Since the actual number of miles used per season is very low, the only added hazard incurred by using the trailer is from punctures and blowouts.

Time spent on the road is a very small portion of the useful life of a cotton trailer. Most of the time it sits empty in the field, or at the gin, either loaded or unloaded. Distances between the field and the gin sel-

TABLE 8.—Estimated Annual Fixed and Variable Costs of Operating a Five-Bale, Steel Cotton Trailer, Louisiana, 1961-62

Item	Cost
	Dollars
Fixed costs:	
Depreciation (straight line, 12 years with no salvage value)[a]	57.17 per year
Interest on investment[b]	20.58 per year
Per mile fixed costs[c]	0.311
Variable costs:	
Tires (one tire per year @ $27.00)	0.108 per mile
Repairs, paint, and grease ($13.00 per year)	0.052 per mile
Total variable costs per mile	0.160

[a] $\frac{C}{N} = D$, where:
C = Replacement cost
N = Number of years used
D = Annual depreciation.

[b] $I = \frac{C}{2}(r)$, where:
I = Average annual interest cost
C = Replacement cost
r = Current average rate of interest = 6%.

[c] Assume 250 miles per trailer per year.

dom exceed 10 or 12 miles. In determining costs per mile it was assumed that trailers traveled 250 miles per season. Fixed and variable trailer costs are shown in Table 8.

Assembly Cost Relationships

The previous section was devoted to examining the nature of costs necessary to assemble seed cotton at the gin. Certain assumptions were made to facilitate the computation of per mile costs of assembly. Fixed labor costs were 46.6¢ per bale, while variable costs per bale mile were 24.2¢.

The density of cotton over a specified area of production may vary widely as the distance from the gin increases. However, in order to facilitate analysis it was assumed that production density was constant over the area at some average level. This is the only practical approach to problems of estimating assembly cost functions.[6]

Table 9 shows the amount of cotton available to a gin for a wide range of field-to-plant travel distances for four levels of production density per square mile. For small volumes, the difference in travel distance for relatively low production density and high production density is quite small. However, for large volumes the difference in travel distance is quite large.

The relation between volume of cotton and the average per bale cost of assembly for four levels of cotton production density is shown in

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[6] Ben C. French, "Some Considerations in Estimating Assembly Cost Functions for Agricultural Processing Operations," *Journal of Farm Economics*, XLII, 1960, p. 769.

TABLE 9.—**Field-to-Gin Travel Distances and Average Cost per Bale for Specified Volumes of Cotton and Four Levels of Production Density, Louisiana, 1961-62**

	Production density per square mile							
Volume	50 Bales		100 Bales		200 Bales		300 Bales	
	Distance	Av. cost	Distance	Av. cost	Distance	Av. cost	Distance	Av. cost
Bales	*Mi.*	*Dol.*	*Mi.*	*Dol.*	*Mi.*	*Dol.*	*Mi.*	*Dol.*
1,000	2.52	.77	1.78	.68	1.26	.62	1.03	.59
2,000	3.56	1.20	2.52	.99	1.78	.83	1.45	.77
3,000	4.37	1.42	3.09	1.14	2.18	.94	1.78	.86
4,000	5.04	1.60	3.56	1.27	2.52	1.04	2.06	.93
5,000	5.64	1.76	3.98	1.38	2.82	1.11	2.30	.99
6,000	6.18	1.90	4.37	1.48	3.09	1.18	2.52	1.05
7,000	6.67	2.02	4.72	1.56	3.33	1.24	2.78	1.10
8,000	7.13	2.14	5.04	1.65	3.56	1.30	2.91	1.15
9,000	7.56	2.24	5.35	1.72	3.78	1.35	3.09	1.19
10,000	7.97	2.34	5.64	1.80	3.98	1.40	3.25	1.23
11,000	8.36	2.44	5.91	1.86	4.18	1.45	3.41	1.27
12,000	8.74	2.54	6.18	1.93	4.37	1.50	3.56	1.31
13,000	9.09	2.62	6.43	1.99	4.54	1.54	3.71	1.35
14,000	9.44	2.71	6.67	2.05	4.72	1.59	3.85	1.38
15,000	9.77	2.79	6.91	2.11	4.88	1.63	3.98	1.42
16,000	10.09	2.87	7.13	2.16	5.04	1.67	4.12	1.45
17,000	10.40	2.94	7.35	2.22	5.20	1.70	4.24	1.48
18,000	10.70	3.02	7.56	2.27	5.35	1.74	4.37	1.51
19,000	11.00	3.09	7.77	2.32	5.49	1.78	4.48	1.54
20,000	11.28	3.16	7.97	2.37	5.64	1.81	4.60	1.56
21,000	11.56	3.23	8.17	2.42	5.78	1.85	4.72	1.59
22,000	11.83	3.30	8.36	2.46	5.91	1.88	4.83	1.62
23,000	12.09	3.36	8.55	2.51	6.05	1.91	4.93	1.65
24,000	12.36	3.42	8.74	2.56	6.18	1.95	5.04	1.67
25,000	12.61	3.49	8.92	2.60	6.30	1.98	5.15	1.70
26,000	12.86	3.55	9.09	2.64	6.43	2.00	5.25	1.72
27,000	13.11	3.61	9.27	2.69	6.55	2.04	5.35	1.75
28,000	13.34	3.66	9.44	2.73	6.67	2.07	5.45	1.77
29,000	13.58	3.72	9.60	2.77	6.79	2.10	5.54	1.80
30,000	13.82	3.78	9.77	2.81	6.90	2.12	5.64	1.82

Table 9 and Figure 2. By using the formulas shown in Appendix A the average cost of assembly can be computed for other densities of cotton production.

Density has only a small influence on assembly costs at low volumes. At the relatively low volume of 1,000 bales, assembly costs per bale vary from 77¢ to 59¢. At the relatively large volume of 30,000 bales these costs range from $1.82 to $3.78 per bale.

The development of average assembly cost estimates for cotton is but one facet in developing optimum or least-cost combinations of ginning and assembling seed cotton. The analysis now proceeds to the development of estimates of per bale ginning costs for various gin sizes and annual volumes. Following this, the task is one of simply adding the two cost functions together.

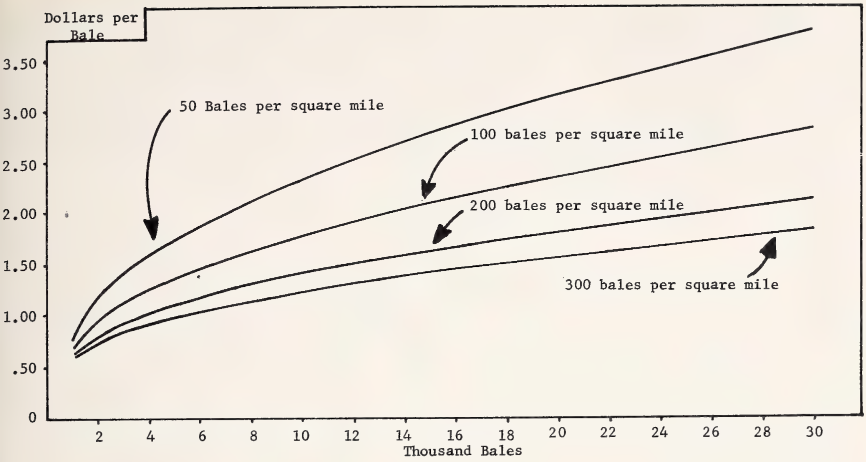

FIGURE 2.—Relation of Average Assembly Cost to Volume of Cotton Supplied to Gin for Four Levels of Production Density, Louisiana, 1961-62.

MODEL GIN COSTS

Cost estimates for alternative size cotton gins can be obtained from existing plants or they may be synthesized much as a contractor does when bidding on the construction of a new building. In this study the two methods were blended somewhat by only obtaining cost data from new gin plants which generally fit the criteria established for synthesizing gin plants.

To assure useful and meaningful cost comparisons between different size cotton gins, the number of alternative methods of ginning a given volume of cotton throughout the harvesting season must be limited. To achieve this comparability the restrictions imposed upon the physical plant and operating conditions must be relatively concise and detailed.

Model Restrictions

Model restrictions necessary to isolate the effects of changes in scale take the form of assumptions concerning the operation of the gin plants and those external factors which influence efficiency within the plant. Insofar as possible these assumptions conform to Louisiana conditions. However, those changes necessary to make the models applicable to the entire Mississippi delta are presumed to be minor. Variations in these restrictions, if applied across the board, would lead to some variation in the level of costs. However, the general relationship of cost to scale would still remain relatively unchanged.

Length of Ginning Season

The uneven annual arrival of cotton at gins constitutes one of the

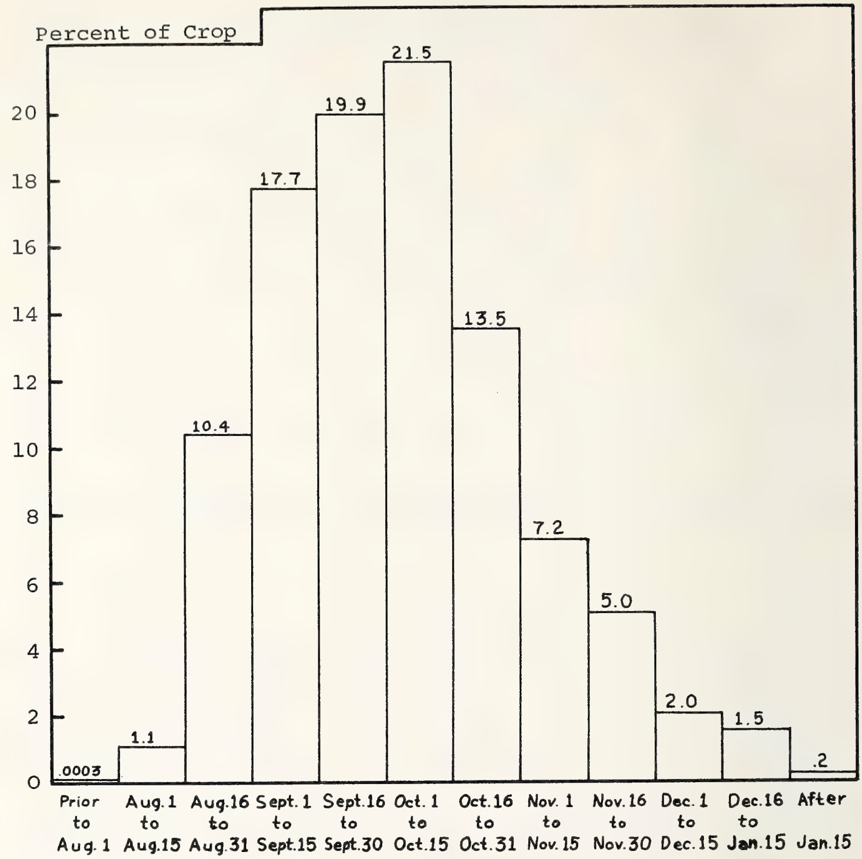

FIGURE 3.—Relative Distribution of Seed Cotton Receipts at Cotton Gins, Louisiana, 1950-59. (Source: U.S. Dept. of Commerce, Bureau of the Census, *Cotton Production and Distribution.*)

most difficult and costly aspects of cotton ginning. On an average, 50 to 70 percent of the annual cotton crop in Louisiana arrives at cotton gins within a six-week period from the first of September to the middle of October (see Figure 3).

For purposes of defining a ginning season, the bulk of the Louisiana cotton crop is harvested and ginned between the first of August and the thirtieth of January. Essentially the season will average about six months, with the season in some years as long as seven months (1961-62) and in others as short as four months (1962-63).

If Sundays and holidays are eliminated, the ginning season will amount to about 152 ginning days. This figure, however, appears to be somewhat misleading because of the method of reporting gin arrivals. This information is reported for the state as a whole. However, on an average, there is a difference of about two weeks between the harvest season in South Louisiana and North Louisiana. When all adjustments are considered, the total number of ginning days available per season amounts to approximately 146. In most cases, however, the gin will actually operate fewer days per season. Ordinarily, gins do not maintain crews at the gin every day during the early and the late part of the season. Rather, the ginner will accumulate enough cotton to run the gin at least a half day.

Length of Ginning Day

Ordinarily, ginners will attempt to gin all cotton sitting on the gin yard before shutting down the gin. Most ginners will admit to operating 14-16 hours with one crew before shutting down if there is cotton on the yard. As a general rule, however, 12 hours is considered a normal working day for a gin crew, not all of which is actual ginning time.

Most ginners will not maintain a gin crew at the gin on the chance that an odd load of cotton will drift in occasionally. The practice is to accumulate enough cotton on the yard to run the gin at least a half day, or about 6 hours. Ginners will gin a single load if the producer insists that he get his trailer back immediately, but where the gin has trailers for use by farmers, it will usually loan him a trailer rather than start the gin.

For purposes of this study it will be assumed that the gin will operate no less than 6 hours per day and in most cases will operate 12 hours per day. The gin will operate two 12-hour shifts when daily receipts exceed the capacity of the gin in a 16-hour period or when daily receipts exceed the capacity of the gin in a 12-hour period if the gin has already switched to two shifts. When the volume is reduced to the point where gin days are appropriate, the gin will operate one 12-hour shift per week until the end of the season.

Gin Capacity

The rated hourly gin capacity as utilized in this study refers to the number of bales of machine-picked cotton which can be ginned in one hour at optimum speed, exclusive of any down-time. The capacity of the gin over any given period of time will be the hourly capacity multiplied by the number of hours in the period and adjusted for an assumed down-time factor. For example, the maximum capacity of a 4-bale-per-hour gin in a 24-hour period with a 15 percent down-time will be 81.6 bales. Annual gin capacity as defined in this study is the amount of cotton which a ginner can expect to receive within the framework of some assumed distribution of seed cotton arrivals at the gin, as shown in Figure 3.

Currently the distribution of cotton receipts at gins closely follows the harvesting of cotton. As long as the present practice of ginning cotton as soon as it arrives at the gin is continued, the harvesting season and the ginning season will be practically synonymous. A 10-year average of the relative distribution of cotton ginnings is shown in Figure 3. While having the usual disadvantages of an average, it does illustrate the skewness of cotton arrivals at gins. This distribution has the added disadvantage of concealing the differences in harvesting seasons between different areas of the state. The problems facing an individual ginner on a particular day during the ginning season may be quite different from the distribution shown in Figure 3.

Despite the limitations of the distribution shown in Figure 3, it does give an indication of the problem faced by ginners and offers a starting point in the search for a solution. Assuming that cotton arrives at the model gins in the pattern indicated in Figure 3, the annual capacity of a gin is determined by the amount of cotton which can be ginned during the peak 15-day period. Thus, if receipts during the peak 15-day period normally include 21.5 percent of the crop, it is reasonable to assume that the gin is operating at full capacity during this period. Assuming the peak 15-day period of harvesting occurs during the period October 1 to October 15, the gin will be operating 24 hours a day for the 15-day period. Using an assumed 15 percent down-time figure, the gin will actually be ginning cotton at its rated hourly capacity for 306 hours out of a possible 360 hours. Assuming further that cotton is received at the gin in the pattern shown in Figure 3, the output of the gin during this 15-day period will be 21.5 percent of the total volume it could normally expect to gin during the season. By allowing the capacity of the gin during the peak 15-day period to represent 21.5 percent of the expected annual receipts, estimates can be made of the expected annual receipts for various size gins (see Table 10). This is defined as the annual capacity of model gins in this study.

The distribution of the annual volume of a 4-bale-per-hour gin computed in the manner outlined above is shown in Figure 4. Similar distributions could be computed for other gin capacities. Only during one period, October 1 to October 15, would the gin be required to operate 24 hours per day for the 15-day period in order to keep up. During the month prior to September 1 and the 3 months following October 31 the gin could handle all receipts with something less than a daily 12-hour shift.

The number of ways in which a cotton ginner could gin the amount of cotton shown in Table 10 are almost limitless. This is evident when it is considered that cotton gins are not compelled to operate on rigid

TABLE 10.—Estimates of Peak Two-Week Cotton Receipts and Annual Capacity for Four Model Gins without Seed Cotton Storage, Louisiana, 1961-62

Gin capacity	Volume during peak two-week period	Annual capacity
Bales per hour	*Bales*	*Bales*
4	1,224	5,693
8	2,448	11,386
12	3,672	17,079
15	4,590	21,348

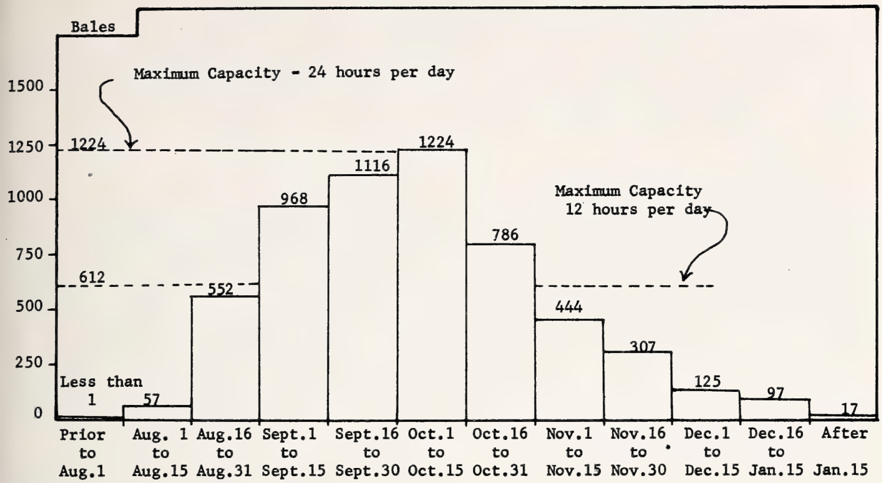

FIGURE 4.—Theoretical Distribution of Cotton Receipts for a 4-Bale-per-Hour Cotton Gin, Louisiana, 1961-62.

time intervals, as for example 4, 8, 12, 16, and 24 hours per day. Moreover, when one considers that the distribution of cotton receipts shown in Figure 3 is a 10-year average and covers rather wide year to year differences, this approach appears to be unmanageable. In order to make meaningful cost comparisons, some simplifying assumptions must be made. Thus, in examining gin cost structures without seed cotton storage, it would appear reasonable to consider total ginning hours outside the distribution pattern of cotton receipts illustrated in Figure 3.

For the four gin sizes considered in this study, the annual volume of cotton shown as capacity in Table 10 could be ginned in about 1,700 hours of operation. This would be the maximum number of hours the gin could ordinarily be expected to operate during the season without some type of seed cotton storage. Conceivably, the gin could operate at any level from zero to 1,700 hours depending on the season, the weather, degree of competition, and a host of other factors. Per bale ginning costs were computed for various levels of gin utilization. Specific levels of utilization were arbitrarily set at 600, 800, 1,000, 1,200, 1,400, and 1,700 hours per season. Later in the study the hours of operation will be increased through the use of storage facilities, and cost relationships reexamined.

Gin Down-Time

Cotton gins cannot run continuously without stopping to grease, clean, oil, and repair the machinery. The amount of time required daily to perform these functions will vary from gin to gin and will depend on the age of the gin, its state of repair, the tightness of the gin, and the prevalent method of harvesting in the area. In view of the assumption of new gins in this study an estimate of 15 percent down-time appears reasonable. Using this assumption, the gin can be expected to actually gin cotton for 10.2 hours out of a normal 12-hour shift. The remaining time is normally spent on routine cleaning and greasing. Repairs are made when the need arises.

Wage Rates

In the majority of Louisiana gins ordinary gin labor was paid $1.00 per hour during the 1961-62 and 1962-63 ginning seasons. Members of the gin crew other than the ginner are usually paid on an hourly basis. Some ginners are paid on an hourly basis, others on an annual basis, and still others are paid a commission on the number of bales ginned. It is not a generally accepted custom to pay a higher overtime wage rate to members of the gin crew working beyond the normal work day or on Sundays and holidays. Some ginners do pay higher wages for overtime, but the number is quite limited.

In those gins where a bookkeeper is employed, salaries will average about $250 per month during the ginning season. However, not all gins employ a bookkeeper.

A management cost is rather difficult to determine. The management function in each gin is unique to that particular enterprise, and wide differences in the scope of the management function exist among gins. In addition, this function is further complicated by the fact that most of the managers interviewed were also owners or part owners. Most of these owner-managers, however, indicated that suitable managers, depending on the size of the gin, could be obtained at salaries ranging from approximately $4,000 to $7,000 per year.

In an attempt to separate out the entrepreneurial or owner return from cotton ginning, management costs will be those aspects of management which are synonymous with supervision.[7] Heady classifies this aspect of management as "human activity of the 'lower order' nature," as compared to the "coordination" aspect of management. Thus, by combining the cost of this lower order type of management into the position of the "ginner-manager" it is felt that entrepreneurial or "risk taking" returns will accrue to the owner in the form of profits.

It was assumed that the ginner-manager was a year-round employee and that he would be responsible for making all out-of-season repairs in the gin. The salaries assigned to these individuals in various size gins are arbitrary, but do represent at least a fair approximation of the salaries paid currently in Louisiana. Most owners indicated that their ginner-managers received certain perquisites not reflected in the salary. No attempt has been made to value these perquisites.

Labor Efficiency

The efficiency of the gin crew will depend to a considerable degree on the ginner-manager's ability, the newness of the gin, the size of the gin, the type of cotton being ginned, and the availability of cotton at the gin. Significant increases in labor efficiency have been reported in the new, high-speed gins. Labor costs in some cases have been cut nearly 50 percent. In conjunction with the assumption of new, high-speed gins in this study, labor efficiency is assumed to be relatively high.

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[7] Earl O. Heady, *Economics of Agricultural Production and Resource Uses* (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1952), p. 465.

Ginners experience considerable difficulty in finding and keeping efficient gin crews. Consequently, they usually try to give them at least a half day of work each time they are called. This is essentially how gin days are handled. The operation of other businesses along with the gin reduces labor problems considerably. In this situation the crew can be pulled off other jobs for short periods to operate the gin. This permits considerable flexibility in gin operation while at the same time providing a means whereby an efficient gin crew can be maintained.

Similar problems are encountered in assembling a night crew when the gin goes on "around-the-clock" operation. The usual procedure is to split the regular crew between the day and night shifts, thus maintaining a core of experienced men on each shift.

When the gin is operating two 12-hour shifts, it is commonly believed that the day crew is the most efficient because of better working conditions, i.e., more light. Oddly enough, however, some ginners report the turnout by the night crew to be equal to or greater than the turnout by the day crew. This is explained by the fact that trailers can be bunched or grouped for individual producers, thus eliminating the need to clear the gin between each trailer. During daylight hours customers are constantly around the gin and usually insist on being ginned in turn.

As a simplifying assumption, the two crews are assumed to be equally efficient.

Size of Gin Crew

The size of the gin crew will vary with the size of the gin and whether the gin is ginning continuously or only intermittently. If the gin is ginning a single trailer of 3 to 5 bales, most gins can be operated with three or four men. Ginning for any length of time, however, will require a full crew. The various labor operations and the number of men required to perform these operations for various size gins are shown in Table 11. This table assumes a highly efficient gin crew. Certain jobs or work assignments within the gin are not well defined. Hence, the man assigned to one position may assist in other jobs throughout the gin. For example, a 4-bale-per-hour gin does not keep the press crew busy at all times; thus, one of these men can very easily move trailers to and away from the sucker pipe.

If the gin is operating 24 hours a day, the day and night crews will be identical except the night crew will not include clerical help in the office.

TABLE 11.—Labor Requirements and Crew Organization for Four Model Gins, Louisiana, 1961-62

Operation	Plant capacity - bales per hour[a]			
	4	8	12	15
	Number of workers			
Move trailers into position and remove empty trailers	—	1	1	1
Operate sucker pipe	1	1[b]	1[b]	1[b]
Handle gin console and watch gin stands	1	1	1	1
Assist on gin stands and watch lint cleaners			1	1
Weigh seed, weigh bales, write tickets, and tag bales		1[d]	1[d]	1[d]
Tie-out bales, wrap press head, turn press, operate press mechanism, roll bale out of press	2[c]	2	2	3
Move bale to storage platform, truck, or freight car, beat-out ties, sample bale		1	1	1
Clerical work (office)	—	1[e]	1[e]	1[e]
Total	4	8	9	10

[a] Rated capacity exclusive of down-time.
[b] Alternates with man shifting trailers on gin yard.
[c] Shifts trailers on gin yard.
[d] Assists with bale sampling and serves as utility man.
[e] Work hours need not correspond to gin crew hours.

Type of Cotton Received

About 50 percent of the 1960-61 Louisiana cotton crop was harvested by mechanical pickers.[8] In some areas of the state, particularly in the Mississippi and Red River valleys, the percentage is believed to be much higher. In 1962 several ginners in this area estimated that about 70 to 80 percent of their gin receipts were harvested by mechanical pickers.

By making the assumption that all cotton ginned by the model gins is harvested by mechanical pickers, the amounts of cotton and trash handled per bale will increase over hand-picked cotton. This premise appears to be valid for planning purposes in view of the continuing trend toward mechanization.

Gin Equipment

The amount of cleaning and conditioning equipment needed in a gin will depend on seasonal weather patterns and harvesting practices utilized in the area. The method of harvesting generally determines the amount of foreign matter which the gin must remove. Hand-picked cotton normally produces the least amount of trash, while machine-stripped cotton produces the greatest amount. Kennerly estimates that 38 percent of the weight of machine-stripped cotton is trash, or about 840 pounds more trash than is found in equivalent hand-picked cotton.[9] Equivalent spindle-picked cotton contains about 200 pounds of trash to the bale. No machine-stripped cotton of any consequence has been reported in Louisiana, although hand-stripped cotton ranged from 1 percent to 15 percent of the crop from 1949 to 1960.[10]

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[8] James F. Hudson, *Louisiana Cotton Quality Statistics and Related Data,* Louisiana Agricultural Experiment Station Bulletin No. 549, Dec. 1961, p. 9.

Current USDA and Louisiana Agricultural Extension Service gin equipment recommendations for Louisiana conditions include two full tower driers, 12 to 14 cylinders of overhead cleaners, a green leaf and stick machine, a green boll trap, extractor feeders, and two stages of lint cleaners.[11] Some gins in Louisiana employ three stages of lint cleaning; however, USDA research indicates that two stages of lint cleaning produce optimum bale values when weight loss is considered.[12]

The model gins constructed in this study are assumed to have sufficient equipment to follow a machine sequence as follows:

1. Green boll trap
2. Automatic feed control
3. Automatic drier control
4. Full tower drier
5. 6- or 7-cylinder incline cleaner
6. Stick and green leaf machine
7. Full tower drier
8. 6- or 7-cylinder incline cleaner
9. Distributor
10. Extractor feeder
11. Gin stand
12. Lint cleaner
13. Lint cleaner
14. Bale press

The equipment in each gin is assumed to be sufficient to handle the rated capacity of the gin with relative ease and no bottlenecks. This equipment capacity will be reflected in the investment costs for various size gins.

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[9] A. B. Kennerly, "Cotton Gins, too, Have Moved West," *Texas Agricultural Progress*, VIII, 1962, pp. 23-24.

[10] Hudson, *op. cit.*, p. 9.

[11] Based on recommendations made by Charles E. Severance, Extension Engineer, Louisiana Agricultural Extension Service, and A. E. Pendleton, Gin Engineer, USDA.

[12] Zolon M. Looney and J. L. Ghetti, *Effects of Tandem Lint Cleaners on Bale Values, Weight Changes, and Prices Received by Farmers*, USDA, Marketing Research Report No. 397, May 1960.

Investment Costs

Investment costs in gins are relatively fixed once the investment has been made in the gin. In cotton gins this is a major cost item and only through increased volume can the investment per unit of output be reduced.

Investment costs were broken down into two major categories — gin structures and gin machinery. Two other investment items, office equipment and gin tractor, were handled separately because of different depreciation periods. Gin buildings were all assumed to be of metal and concrete construction and to include the main gin buildings with attached double wagon shed, dust room, and bale shed along with the necessary foundation. Auxiliary buildings such as the seed house, bale storage platform, incinerator, and office building were also included in this category. Gin machinery and equipment includes all equipment within the gin proper, including the CO_2 fire system, electric motors, wiring, spare parts, and hand tools. Ginning machinery was grouped according to the gin function performed.

Replacement costs for four model gin plants of varying size are shown in Tables 12, 13, and 14.

TABLE 12.—Estimated Gin Structure Replacement Costs, Four Model Gin Plants, Louisiana, 1961-62

	Gin capacity - bales per hour			
Structure	4 Bales	8 Bales	12 Bales	15 Bales
	1,000 Dollars	*1,000 Dollars*	*1,000 Dollars*	*1,000 Dollars*
Gin building and foundation	20.0	30.0	35.5	39.0
Seed house (elevated)	3.8	5.7	7.9	9.0
Incinerator	3.0	6.0	8.0	9.0
Office	2.0	2.0	2.5	2.5
Total gin structures	28.8	43.7	53.9	59.5

TABLE 13.—Estimated Gin Machinery and Equipment Replacement Costs, Four Model Gin Plants, Louisiana, 1961-62

	Gin capacity - bales per hour			
Item	4 Bales	8 Bales	12 Bales	15 Bales
	1,000 Dollars	*1,000 Dollars*	*1,000 Dollars*	*1,000 Dollars*
Receiving, drying, and conditioning equipment	41.1	82.7	100.7	122.8
Gin stands	9.3	12.5	19.4	23.6
Lint flue, lint cleaners, and condensor	21.3	29.6	44.5	54.2
Bale press	17.5	18.8	18.8	22.8
Bale scales, seed scales, and seed handling equipment	3.6	6.7	7.0	8.4
Hull handling equipment	1.3	2.0	2.4	3.0
Electric motors, wiring, and relay equipment	12.5	20.2	29.3	35.8
Total machinery and equipment	106.6	172.5	222.1	270.6

TABLE 14.—Estimated Total Gin Replacement Costs, Four Model Gin Plants, Louisiana, 1961-62

Item	Gin capacity - bales per hour			
	4 Bales	8 Bales	12 Bales	15 Bales
	1,000 Dollars	*1,000 Dollars*	*1,000 Dollars*	*1,000 Dollars*
Gin structures	28.8	43.7	53.9	59.5
Gin machinery and equipment	106.6	172.5	222.1	270.6
Gin tractor	1.7	1.7	1.7	1.7
Office equipment	1.0	1.0	1.5	1.5
Total gin replacement costs	138.1	218.9	279.2	333.3
Average investment cost per bale of capacity	34.5	27.4	23.3	22.2

Operating Costs

The operating costs of any processing plant are composed of both fixed and variable components. In some instances certain of these costs have both fixed and variable characteristics. In this study costs were classified either as fixed or as variable even though some problems were encountered in doing so.

Fixed Costs

Salaries — Fixed costs include the salary of the ginner-manager and the salary of a secretary or bookkeeper.

In constructing gin cost models, the ginner-manager's annual salary was computed at $4,000 for 4-bale-per-hour gins, $5,000 for 8-bale gins, $6,000 for 12-bale gins, and $7,000 for 15-bale gins.

Office salaries include the wages paid the bookkeeper on a 4-month basis for the 8-bale-per-hour gin, and on a 6-month basis for the 12- and 15-bale-per-hour gins. Wages of the bookkeeper were assumed to be $250 per month for all size gins. It was further assumed that the duties of a bookkeeper would be handled by the ginner-manager for the 4-bale-per-hour gin, and consequently no office salary was shown for this size gin.

Depreciation — Depreciation costs on the gin buildings and machinery are at best only estimates. It should be recognized that costs can be manipulated to a considerable degree by the assumptions used in computing depreciation costs. Ginning costs are particularly susceptible to this arbitrariness because of the relatively high investment costs and the short ginning season.

The principal difference in ginning costs between Area I and Area II results from different time periods over which depreciation costs are spread. In Area I, ginners can anticipate longer periods during which they can expect volumes approaching those currently available. Because of the greater uncertainty involved, a ginner or investor in Area II would insist that his investment be repaid in a shorter time period. Little empirical data were available for use in estimating applicable depreciation periods between the two areas. Depreciation schedules for Area I were based on guidelines established by the Internal Revenue Service, while depreciation schedules for Area II were selected to reflect the shorter amortization period.[13]

Thus, in Area I gin buildings were depreciated over 30 years, while 10 years was used in Area II. No salvage value was assumed for gin buildings in either area. Gin building depreciation was charged to operating costs at the rate of 3.3 percent per year in Area I and at the rate of 10 percent in Area II. Gin machinery and equipment were assumed to have a 15-year useful life in Area I and were written off at 6.6 percent per year. The depreciation time period for machinery and equipment was shortened to 10 years in Area II and charged to operating costs at the rate of 10 percent per year. Since gin equipment currently becomes obsolete at an unusually rapid rate and will ordinarily only bring scrap metal prices, no salvage value was assumed. Because of their limited use, tractors used in moving trailers about the gin yard were assumed to have a useful life of 5 years in both areas. The original cost less a salvage or trade-in value of $500 was charged to operating costs at the rate of 20 percent per year. Office furniture and fixtures, assumed to have a useful life of 10 years in both areas with no salvage value, were written off at 10 percent per year. Only a minimum of office equipment is needed to conduct the ginning business. Most gin offices are larger and better equipped than necessary because of other enterprises. Only a part of this, however, can be charged to the ginning operation.

Interest on Investment – In this study it was assumed that interest on invested capital constituted a necessary cost of operating a gin business. Interest on investment was calculated at 6 percent on the average value of the gin plant and other fixed facilities. The 6 percent rate represents an average interest rate based on rates currently being paid by the ginners interviewed.

Taxes – Those taxes which are considered along with other fixed costs are for the most part ad valorem taxes levied by city and parish governments. Tax rates used in this study were obtained from published tax information for the State of Louisiana. Computations were based on an average value of the fixed asset over its useful life. The appraised value was set at one-fifth the average value. A tax rate of 50 mills per dollar of assessed valuation was used to determine annual ad valorem tax costs.

Insurance – The insurance costs included in this section are those determined to be relatively "fixed" as discussed earlier and refer to fire and comprehensive insurance on the gin buildings and equipment. Rates were obtained from the Louisiana Rating and Fire Prevention Bureau, and where conditions permitted, the minimum rate was used. In order to take the minimum rate, the model gins were assumed to meet certain requirements as specified by the Bureau. When all deductions were taken, the annual fire insurance rate used was $1.24 per $100 of value for the main gin building and equipment, and $1.31 per $100 of value for auxiliary buildings.

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[13] United States Treasury Department, Internal Revenue Service, *Depreciation Guidelines and Rules,* Publication No. 456 (7-62), July 1962.

The annual rate used for comprehensive coverage of the gin equipment and gin buildings, when constructed of noncombustible material, was 22¢ per $100 of value. This rate was applied to 90 percent of the gin replacement value.

Variable Costs

Labor – With the exception of office salaries and the ginner-manager's salary, labor costs are directly related to volume. As a general rule in Louisiana, gin labor is paid $1.00 per hour with no provision made for increased rates for overtime. Current legislative patterns indicate that eventually cotton gin labor may be included under the minimum wage laws. For this reason, two hourly wage rates, $1.00 and $1.25, were used in computing per bale ginning costs. The labor costs shown reflect the employer's contribution to Social Security of 3.125 percent of wages.

Bagging and Ties – The cost of bagging and ties will vary among gins, depending on the quality used. Some ginners buy used bagging while others use the more expensive close-weave bagging. The rate used in this study is $2.50 per pattern, with no volume discount considered.

Power – The gins in this study are assumed to be powered completely by electricity. Horsepower requirements of model gins are patterned after the four new gins currently operating in Louisiana. Estimates of kilowatts used per hour were made using a standard engineering factor of .746 kilowatt per hour multiplied by the number of horsepower in the gin. This estimate was in turn checked with power costs as reported by the four new gins. In all cases differences were relatively small.

The electric rate structure for an all-electric cotton gin in Winnsboro, Louisiana, was selected as typical for use in the model gins. The rate used was as follows:[14]

4.54¢ per K.W.H. – first 1,000 bales ginned per season;
4.04¢ per K.W.H. – next 1,000 bales ginned per season;
3.54¢ per K.W.H. – all over 2,000 bales ginned per season.

Minimum bill – $8.00 per season per horsepower of connected load. In addition, a 0.5¢ per K.W.H. prompt payment discount was taken.

Although the electric rates used are those currently in effect, there is some agitation on the part of electric power companies in Louisiana to revise this rate structure downward, thereby providing a more favorable power cost to cotton gins. Currently, through a technicality, one power company, for experimental purposes, has two cotton gins on a rate structure applicable to small industries. Relative to power costs in other comparable gins, costs per bale have been approximately halved. Should a revised rate structure be approved, per bale power costs for larger gins having substantial volumes will drop significantly.

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[14] U.S. Federal Power Commission, *National Electric Rate Book, Louisiana,* Washington, D.C., September 1960, p. 7.

Drier Fuel – The natural gas rate structure for commercial installations in Winnsboro, Louisiana, was also selected as typical for use in this study. The gas used is assumed to contain, on an average, 1,000 BTU per cubic foot. Natural gas is measured in cubic feet and for commercial users the price is quoted in MCF, or 1,000 cubic feet. Hence, a three million-BTU burner operating at rated capacity will deliver three million BTU of heat in one hour and will consume three MCF of gas.

The rates for natural gas used in this study are as follows:[15]

$10.00 for first 10 MCF (monthly minimum);
25¢ per MCF for next 90 MCF;
22¢ per MCF for all over 100 MCF.

The minimum is $10.00 per month for any six consecutive months.

The use of drying fuel will vary widely with the moisture content of the cotton. When the heat control is done manually there is a tendency to overdry. This problem is reduced or eliminated in this study by assuming that all gins are equipped with automatic drier control devices which regulate the heat so that the cotton has a 6 percent moisture content when it reaches the saws. This assumes that cotton has at least 6 percent moisture when it arrives at the gin, a relatively safe assumption for Louisiana.

Repair and Maintenance – Gin repair and maintenance costs are a function of numerous factors, such as volume ginned, amount of foreign matter to be removed, size of the gin, age of the gin, and gin management. Relative to other gin cost studies, repair and maintenance cost estimates in this study are low because of the assumptions that gins are new and that all cotton is harvested with spindle pickers. Repair and maintenance costs are at best only rough approximations and under actual conditions will vary widely between comparable gins. Estimates used in this study were developed from published gin cost studies, and estimates by managers of the four new gins, and by cotton gin specialists. Again these estimates do not represent averages, but are believed to be typical repair and maintenance costs for new gins operating under Louisiana conditions.

Insurance – Those insurance costs which vary closely with volume are "cotton products" insurance, workmen's compensation insurance, and general liability insurance. Annual premium rates on "cotton products" or "gin yard" insurance range from $3.50 to $4.50 per $100.00 of value. Since nearly "ideal" or optimum conditions were assumed in most of the study, the same assumption was made relative to cotton products sitting on the gin yard, and the minimum rate was used. This type of coverage is usually a "reporting" policy, and for this reason it was assumed that there was never more than one day's ginnings on the yard at any time. The average number of bales on the gin yard during each month was estimated and an average value computed on the basis of 500-pound bales

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[15] Natural gas rates were obtained from the Louisiana Public Service Commission, Baton Rouge, Louisiana, and the Louisiana Gas Service Company, Winnsboro, Louisiana.

TABLE 15.—Fixed, Variable, and Total Ginning Costs for a Four-Bale-per-Hour Model Gin Operated for Specified Hours Annually, Two Hourly Wage Rates, Areas I and II, Louisiana, 1961-62

Item of cost	Annual hours of operation[a]					
	600	800	1,000	1,200	1,400	1,700
	Dollars					
Fixed costs per bale						
Area I	9.41	7.05	5.64	4.70	4.03	3.32
Area II	12.09	9.07	7.25	6.04	5.18	4.27
Variable costs per bale						
Areas I and II						
($1.00 per hour)	7.14	6.93	6.75	6.60	6.57	6.52
($1.25 per hour)	7.39	7.18	7.00	6.91	6.81	6.76
Total costs per bale						
Area I						
($1.00 per hour)	16.55	13.98	12.39	11.30	10.60	9.84
($1.25 per hour)	16.80	14.23	12.64	11.61	10.84	10.08
Area II						
($1.00 per hour)	19.23	16.00	14.00	12.64	11.75	10.79
($1.25 per hour)	19.48	16.25	14.25	12.95	11.99	11.03

[a] The relation between hours of operation and volume of cotton ginned is linear. The number of bales ginned for each discrete number of hours operated is shown in Appendix Tables 1 and 2.

TABLE 16.—Fixed, Variable, and Total Ginning Costs for an Eight-Bale-per-Hour Model Gin Operated for Specified Hours Annually, Two Hourly Wage Rates, Areas I and II, Louisiana, 1961-62

Item of cost	Annual hours of operation[a]					
	600	800	1,000	1,200	1,400	1,700
	Dollars					
Fixed costs per bale						
Area I	7.36	5.52	4.42	3.68	3.15	2.60
Area II	9.48	7.11	5.69	4.74	4.06	3.35
Variable costs per bale						
Areas I and II						
($1.00 per hour)	6.61	6.45	6.33	6.27	6.20	6.16
($1.25 per hour)	6.86	6.70	6.58	6.52	6.45	6.41
Total costs per bale						
Area I						
($1.00 per hour)	13.97	11.97	10.75	9.95	9.35	8.76
($1.25 per hour)	14.22	12.22	11.00	10.20	9.60	9.01
Area II						
($1.00 per hour)	16.09	13.56	12.02	11.01	10.26	9.51
($1.25 per hour)	16.34	13.81	12.27	11.26	10.51	9.76

[a] The relation between hours of operation and volume of cotton ginned is linear. The number of bales ginned for each discrete number of hours operated is shown in Appendix Tables 4 and 5.

TABLE 17.—Fixed, Variable, and Total Ginning Costs for a Twelve-Bale-per-Hour Model Gin Operated for Specified Hours Annually, Two Hourly Wage Rates, Areas I and II, Louisiana, 1961-62

Item of cost	Annual hours of operation[a] 600	800	1,000	1,200	1,400	1,700
	Dollars					
Fixed costs per bale						
Area I	6.23	4.67	3.74	3.11	2.67	2.20
Area II	8.04	6.03	4.82	4.02	3.44	2.84
Variable costs per bale						
Areas I and II						
($1.00 per hour)	6.08	5.94	5.86	5.78	5.73	5.70
($1.25 per hour)	6.27	6.13	6.05	5.97	5.92	5.89
Total costs per bale						
Area I						
($1.00 per hour)	12.31	10.61	9.60	8.89	8.40	7.90
($1.25 per hour)	12.50	10.80	9.79	9.08	8.59	8.09
Area II						
($1.00 per hour)	14.12	11.97	10.68	9.80	9.17	8.54
($1.25 per hour)	14.31	12.16	10.87	9.99	9.36	8.73

[a] The relation between hours of operation and volume of cotton ginned is linear. The number of bales ginned for each discrete number of hours operated is shown in Appendix Tables 7 and 8.

TABLE 18.—Fixed, Variable, and Total Ginning Costs for a Fifteen-Bale-per-Hour Model Gin Operated for Specified Hours Annually, Two Hourly Wage Rates, Areas I and II, Louisiana, 1961-62

Item of cost	Annual hours of operation[a] 600	800	1,000	1,200	1,400	1,700
	Dollars					
Fixed costs per bale						
Area I	5.91	4.44	3.55	2.96	2.53	2.09
Area II	7.61	5.71	4.57	3.81	3.26	2.69
Variable costs per bale						
Areas I & II						
($1.00 per hour)	5.85	5.72	5.64	5.59	5.54	5.52
($1.25 per hour)	6.02	5.90	5.82	5.76	5.72	5.69
Total costs per bale						
Area I						
($1.00 per hour)	11.76	10.16	9.19	8.55	8.07	7.61
($1.25 per hour)	11.93	10.34	9.37	8.72	8.25	7.78
Area II						
($1.00 per hour)	13.46	11.43	10.21	9.40	8.80	8.21
($1.25 per hour)	13.63	11.61	10.39	9.57	8.98	8.38

[a] The relation between hours of operation and volume of cotton ginned is linear. The number of bales ginned for each discrete number of hours operated is shown in Appendix Tables 10 and 11.

and an average value of 32¢ per pound. The insurance rate was then applied to this average value of baled cotton.

The same procedure and assumptions were used in computing the average inventory value and insurance costs for cottonseed. It was further assumed that about 800 pounds of cottonseed would be produced from each 500-pound bale of lint and that the average value of cottonseed was $45 per ton.

Workmen's compensation, while considered a form of tax by some, is a compulsory form of insurance which protects the worker when injured on the job. All employees in the gin or working on the gin yard are classified as "cotton gin operators." The rate for this category is currently $8.12 per $100 of wages up to a maximum of $5,200 per year for each employee. Office help employed in a separate building or on a separate floor from the gin proper are considered as "clerical" employees. The rate for this group is 10¢ per $100 of wages with a maximum of $5,200 per year for each employee.

General liability insurance protects the ginner from liability resulting from bodily injury to employees or others. The rate for the minimum coverage of $5,000 and $10,000 for bodily injury for each accident is 17¢ per $100 of payroll.

Other Expenses — Other gin expenses such as gin supplies, travel expenses, office supplies, telephone and telegraph expenses, legal and audit fees, and miscellaneous items were estimated from previous gin

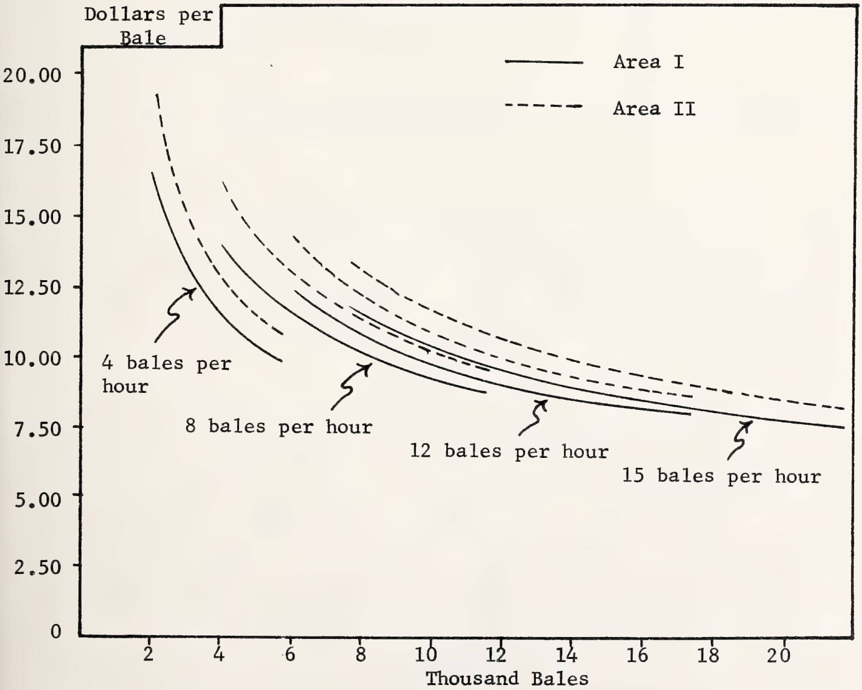

FIGURE 5.—Average per Bale Costs of Ginning for 4-, 8-, 12-, and 15-Bale-per-Hour Model Gins, $1.00 per Hour Wage Rate, Areas I and II, Louisiana, 1961-62.

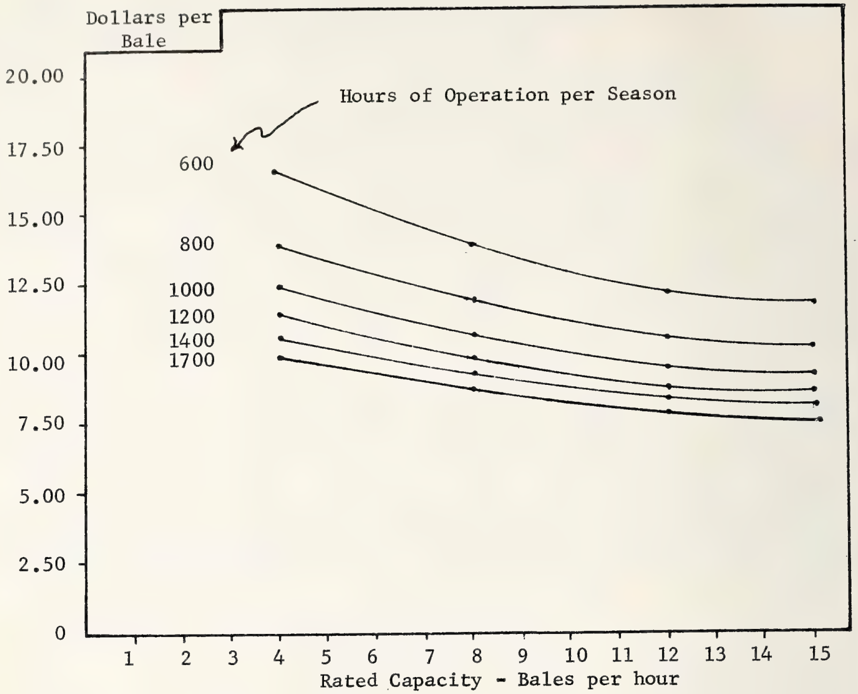

FIGURE 6.—Relation of Average Ginning Costs to Plant Scale, Area I, $1.00 per Hour Wage Rate, Louisiana, 1961-62.

studies. Due allowance was made for the fact that the model gins were assumed to be new, all-electric gins.

Detailed estimates of fixed and variable costs for specified volumes in both production areas are shown in Appendix Tables 1 through 12. Fixed, variable, and total costs of ginning are summarized for various size model gins in Tables 15 through 18.

The general shape and relationships of average ginning costs for various size gins are shown in Figure 5 for both Areas I and II. These average cost curves change very little when the second hourly wage rate, $1.25, is used. Costs are reduced sharply in the smaller capacity gins with relatively small increases in volume. In the larger gins much greater increases in volume are necessary to achieve equivalent cost reductions.

Economies of scale associated with cotton gins are shown in Figure 6. As the number of hours operated each season increases, the average unit cost of ginning decreases substantially for all plants, but greater reductions are encountered with the small plants. For example, average unit costs for a 4-bale-capacity plant operating 600 hours annually are $16.58 and only $9.86 for the same plant operating 1,700 hours annually. Comparable costs for a 15-bale-per-hour plant are $11.76 and $7.61.

In addition, the magnitude of scale economies decreases as the number of hours operated is increased. As plant size is increased, average unit costs decrease at a decreasing rate over the entire range of plant sizes considered.

Combined Assembly and Ginning Costs

To obtain a combined estimate of the costs associated with the assembly and ginning functions, the average assembly cost estimates were added to the average ginning cost estimates. The combined costs of assembly and ginning are shown in Appendix Tables 13 through 16. The relation of combined average assembly and ginning costs to volume is shown in Figure 7 for an area with a production density of 50 bales per square mile and a $1.00 per hour wage rate.

No matter what density of production, the combined costs of assembly

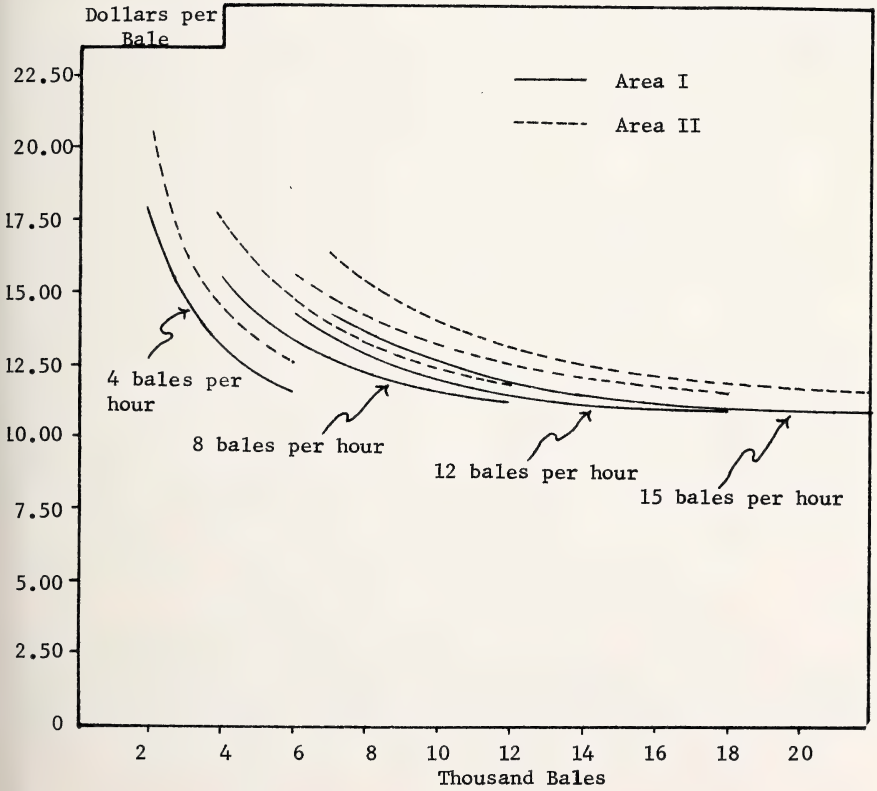

FIGURE 7.—Combined per Bale Costs of Assembly and Ginning for 4,- 8-, 12-, and 15-Bale-per-Hour Model Gins, $1.00 per Hour Wage Rate, Production Density of 50 Bales per Square Mile, Areas I and II, Louisiana, 1961-62.

and processing continue to decline over the range of volumes considered. This implies that ginners can achieve lower per bale ginning costs by taking steps to increase volume. However, the ginner will undoubtedly be compelled to share these efficiencies with the farmer in the form of lower ginning charges, in order to induce the farmer to haul his cotton farther.

STORAGE AS A METHOD OF INCREASING ANNUAL CAPACITY

The problems of cotton ginners relative to high investment costs and short ginning seasons were discussed at length in earlier sections of this study. The relatively high investment costs associated with cotton gins were demonstrated in the previous section. In light of the high investment cost of adding additional gin capacity to handle a six- to eight-week period of heavy cotton arrivals, it appears worthwhile to examine other alternatives.

The estimates of ginning costs previously developed are based on an assumed distribution of seed cotton arrivals at gins. This distribution essentially set the upper limit of annual gin capacity. Alterations in this distribution could either increase or decrease the annual capability of the gin. Since the rate dimension in cotton gins can be varied relatively little, the purpose of this section will be to study the alternative of altering the availability of cotton at the gin in such a manner as to lengthen the total number of hours the gin can be operated during any given ginning season. This involves added costs and the problem becomes one of making cost comparisons between alternative methods of increasing the annual capacity of cotton gins. While there are other methods of increasing gin capacity, the analysis in this study will be limited to cost comparisons between two methods. Basic costs involved in the first method, increasing the rated hourly ginning capacity of the plant, were discussed in the previous section. The second method of increasing capacity, by storing seed cotton at the gin, was analyzed and cost comparisons were made between the two methods.

Feasibility of Seed Cotton Storage

One of the early studies of the effect of seed cotton storage on lint quality indicated that cotton with moisture level of 14 percent or less could be stored with no detrimental effect on lint quality.[16] More recent studies, however, indicate storage is feasible with even higher levels of moisture.[17] While preliminary in nature, these studies do appear encouraging. On the basis of these preliminary studies and the experience of ginners in Texas and California with similar basket storage systems, it was assumed that most seed cotton could be stored in open mesh baskets in Louisiana with no quality deterioration. The further assumption was made that ginners would exercise considerable discretion in selecting between cotton going into storage and cotton to be ginned immediately. To this end, the investment costs associated with the storage system include the cost of a portable moisture meter.

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[16] Z. M. Looney and C. C. Speakes, "Conditioning and Storage of Seed Cotton with Special Reference to Mechanically Harvested Cotton," USDA, OMA, Washington, D.C., March 1952, p. 11, Processed.

Method of Storage

The practice of storing seed cotton at gins is not new. While the practice has declined in the last 30 years, a number of cotton gins in Louisiana still maintain and use on a limited scale some type of permanent seed cotton storage facilities. Seed cotton storage at gins today is accomplished by essentially one of two methods: (1) permanent storage buildings with blower and/or sucker connections to the gin, and (2) baskets or movable racks which are moved about the gin yard for loading and unloading. A third method might be included, i.e., storage on the gin yard in wheel trailers. However, this would seem to be a type of basket storage, with the containers or trailers costing considerably more than baskets because of the running gear.

In this study a basket system was analyzed. The basic investment and operating costs necessary in making cost comparisons between the two methods of increasing gin capacity were obtained by personal interview with the ginner operating the facility.

The storage facilities under consideration consisted of 5-bale, open-mesh baskets constructed of treated lumber (Illustration 1), hydraulic lift dollies used to transport the baskets to and from loading and unloading (Illustration 2), an elevated unloading machine consisting of an electric motor, rembert-type fan, and cyclone (Illustration 3), tractors equipped with extra-large hydraulic pumps and oil tanks (Illustration 4), and pole sheds to house the storage baskets. Experience of ginners in drier climates than Louisiana indicates pole sheds to be the most economical method of protecting cotton from the weather.

Cost of Basket Storage

The costs of storage will depend on the amount of storage the ginner wishes to provide. The extent to which a ginner can extend his

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[17] F. B. Anderson and B. A. Waddle, "Effects of Storing Seed Cotton," *Arkansas Farm Research,* XI, 1962, 3; F. B. Anderson and B. A. Waddle, *Effects of Storing Seed Cotton in Bales on Quality and Value of Lint,* Arkansas Agricultural Experiment Station, Mimeo Series No. 117, August 1962; V. Alonzo Metcalf, *Store Cotton Before Ginning?,* Missouri Agricultural Experiment Station, Special Report No. 20, September 1962.

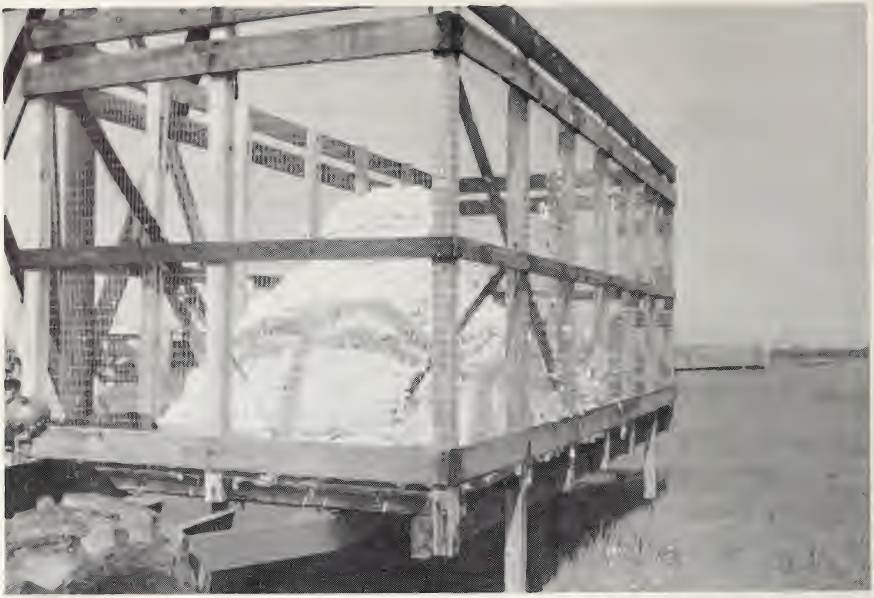

ILLUSTRATION 1.—Details of 5-Bale Seed Cotton Storage Baskets, Louisiana, 1961-62.

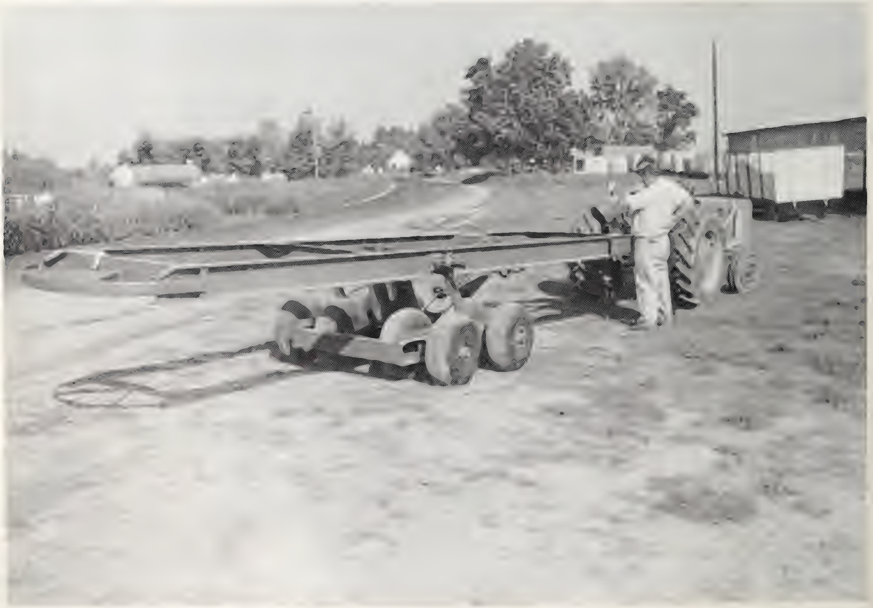

ILLUSTRATION 2.—Hydraulic Lift Dolly Used to Move Storage Baskets Around the Gin Yard, Louisiana, 1961-62.

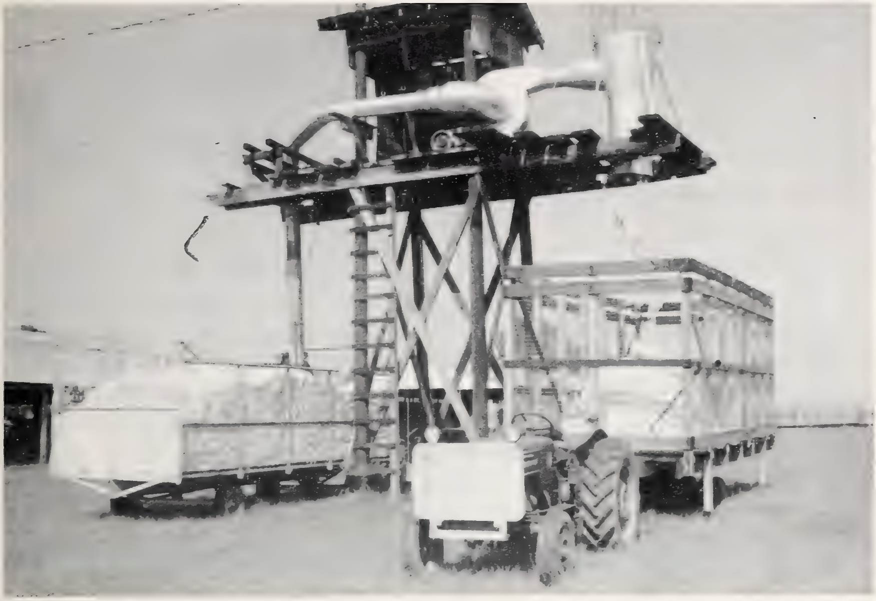

ILLUSTRATION 3.—Elevated Facility Used to Transfer Seed Cotton from Trailer to Storage Basket, Louisiana, 1961-62.

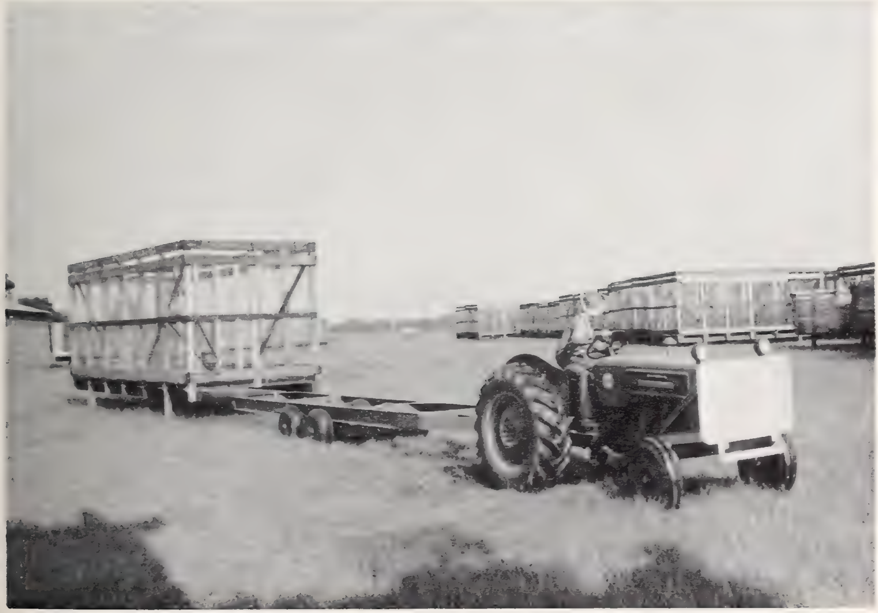

ILLUSTRATION 4.—Tractor, Hydraulic Lift Dolly, and 5-Bale Basket Used in Seed Cotton Storage System, Louisiana, 1961-62.

ginning season is limited by the length of time cotton can remain in storage and the amount of capital available. Consequently, certain assumptions must be made in order that meaningful cost comparisons can be made. In addition, since costs were developed in the previous section at discrete capacities of 4, 8, 12, and 15 bales per hour, the assumption is made that ginning cost relationships at other discrete capacities between those specified are linear.

Investment Costs

Replacement costs are estimated for two levels of annual capacity. In one case the annual capacity of the gin, as discussed in a previous section, is increased by 25 percent and in the other case this capacity is increased by 50 percent. No attempt was made to increase the annual capacity of a 15-bale-per-hour gin since cost estimates for larger gins are not available for making comparisons. In all cases replacement costs per bale of capacity decrease as the capacity is increased from 25 percent to 50 percent. Replacement costs of a basket-type seed cotton storage system for three gin sizes are shown in Table 19.

TABLE 19.—Estimated Replacement Costs of Seed Cotton Storage Facilities Needed to Increase Gin Capacity 25 Percent and 50 Percent, Three Model Gins, Louisiana, 1961-62

Item	4-Bale-per-hour gin		8-Bale-per-hour gin		12-Bale-per-hour gin	
	Percent increase in capacity					
	25	50	25	50	25	50
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Baskets, 5-bale capacity	17,490	45,375	35,145	90,750	52,800	136,125
Hydraulic lift dolly	2,000	2,000	2,000	2,000	2,000	3,000
Basket loading facility	1,700	1,700	1,700	2,300	2,300	4,000
Tractors	2,000	2,000	2,000	2,000	2,000	3,850
Pole sheds	17,808	46,200	35,784	92,400	53,760	138,600
Moisture meter	400	400	400	400	400	400
Total replacement costs	41,398	97,675	77,029	189,850	113,260	285,975
Per bale of storage cap.	77.52	71.09	72.19	69.04	70.74	69.34
Per bale stored	38.73	22.10	36.11	21.45	53.09	21.56

Operating Costs

Fixed, variable, and total costs of operating a storage system at two levels of increased capacity are shown in Table 20 for three gin sizes. Fixed and variable costs of operating the storage system are estimated in the same manner utilized earlier in estimating ginning costs. For all three gin sizes the average per bale costs of storage, when spread over all bales ginned during the season, increase as the volume of cotton available through storage is increased from 25 percent to 50 percent. These unit costs increase as volume is increased because a greater percentage of the total annual receipts must be stored. Only the 25 percent level of increased capacity has been computed in order to make cost comparisons between the storage method and the increased gin capacity method of increasing annual capacity.

Combined per bale ginning and storage costs for the three gin sizes operated at volumes which approximate a 25 percent increase in capacity are shown in Tables 21 through 23. A more detailed breakdown of these storage costs is shown in Appendix Tables 17 through 19.

TABLE 20.—Fixed, Variable, and Total Costs of Storing Seed Cotton by Basket Method, Increased Gin Capacity of 25 Percent and 50 Percent, Three Model Gins, Louisiana, 1961-62

Item	4-Bale-per-hour gin		8-Bale-per-hour gin		12-Bale-per-hour gin	
	Percent increase in capacity					
	25	50	25	50	25	50
			Dollars			
Fixed costs:						
Depreciation	3,093	7,301	5,757	14,188	8,461	22,734
Interest on investment	1,242	2,930	2,311	5,696	3,398	8,579
Insurance	570	1,345	1,061	2,614	1,560	3,938
Taxes	207	488	385	949	566	1,430
Total fixed costs	5,112	12,064	9,514	23,447	13,985	36,681
Variable costs:						
Labor ($1.00)	441	1,823	880	1,825	661	2,736
($1.25)	551	2,279	1,100	2,281	826	3,420
Power	170	702	338	1,405	508	2,106
Fuel, oil, grease	43	177	85	354	128	531
Repairs & maintenance	196	365	303	660	410	1,020
Yard insurance	16	67	33	133	49	203
Compensation & liability ins.						
($1.00)	35	147	71	147	53	220
($1.25)	44	183	88	184	66	275
Total variable costs						
($1.00)	901	3,281	1,710	4,524	1,809	6,816
($1.25)	1,020	3,773	1,947	5,017	1,987	7,555
Total costs						
($1.00)	6,013	15,345	11,224	27,971	15,794	43,497
($1.25)	6,132	15,837	11,461	28,464	15,972	44,236
Total cost per bale ginned						
($1.00)	.84	1.80	.79	1.64	.74	1.70
($1.25)	.86	1.85	.80	1.67	.75	1.73
Total bales ginned (number)	7,116	8,539	14,232	17,079	21,349	25,618
Total bales stored (number)	1,069	4,420	2,133	8,849	3,202	13,266

TABLE 21.—Combined per Bale Ginning and Storage Costs for a Four-Bale-per-Hour Gin Operated at Specified Annual Volumes, Areas I and II, Two Wage Rates, Louisiana, 1961-62

Annual volume	Ginning costs per bale		Storage costs per bale		Total costs per bale	
	$1.00 per hour	$1.25 per hour	$1.00 per hour	$1.25 per hour	$1.00 per hour	$1.25 per hour
Bales	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
			Area I			
2,000	16.70	16.90	2.56	2.56	19.26	19.46
3,000	13.25	13.60	1.70	1.70	14.95	15.30
4,000	11.40	11.70	1.28	1.28	12.68	12.98
5,000	10.40	10.60	1.02	1.02	11.42	11.62
6,000	9.75	10.05	.86	.86	10.61	10.91
7,000	9.22	9.45	.83	.85	10.05	10.30
			Area II			
2,000	19.40	19.80	2.56	2.56	21.96	22.36
3,000	15.15	15.40	1.70	1.70	16.85	17.10
4,000	12.75	13.05	1.28	1.28	14.03	14.33
5,000	11.50	11.70	1.02	1.02	12.52	12.72
6,000	10.65	10.90	.86	.86	11.51	11.76
7,000	10.00	10.23	.83	.85	10.83	11.08

TABLE 22.—Combined per Bale Ginning and Storage Costs for an Eight-Bale-per-Hour Gin Operated at Specified Annual Volumes, Areas I and II, Two Wage Rates, Louisiana, 1961-62

Annual volume	Ginning costs per bale		Storage costs per bale		Total costs per bale	
	$1.00 per hour	$1.25 per hour	$1.00 per hour	$1.25 per hour	$1.00 per hour	$1.25 per hour
Bales	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
			Area I			
4,000	14.10	14.30	2.38	2.38	16.48	16.68
5,000	12.45	12.75	1.90	1.90	14.35	14.65
6,000	11.40	11.65	1.59	1.59	12.99	13.24
7,000	10.60	10.90	1.36	1.36	11.96	12.26
8,000	10.00	10.30	1.19	1.19	11.19	11.49
9,000	9.55	9.80	1.06	1.06	10.61	10.86
10,000	9.20	9.40	.95	.95	10.15	10.35
11,000	8.90	9.10	.86	.86	9.76	9.96
12,000	8.65	8.90	.81	.81	9.46	9.71
13,000	8.45	8.70	.78	.78	9.23	9.48
14,000	8.28	8.50	.79	.79	9.07	9.29
			Area II			
4,000	16.20	16.45	2.38	2.38	18.58	18.83
5,000	14.15	14.50	1.90	1.90	16.05	16.40
6,000	12.85	13.15	1.59	1.59	14.44	14.74
7,000	11.90	12.10	1.36	1.36	13.26	13.46
8,000	11.10	11.35	1.19	1.19	12.29	12.54
9,000	10.55	10.75	1.06	1.06	11.61	11.81
10,000	10.10	10.30	.95	.95	11.05	11.25
11,000	9.65	9.90	.86	.86	10.51	10.76
12,000	9.40	9.65	.81	.81	10.21	10.46
13,000	9.13	9.35	.78	.78	9.91	10.13
14,000	8.90	9.12	.79	.79	9.69	9.91

TABLE 23.—Combined per Bale Ginning and Storage Costs for a Twelve-Bale-per-Hour Gin Operated at Specified Annual Volumes, Areas I and II, Two Wage Rates, Louisiana, 1961-62

Annual volume	Ginning costs per bale		Storage costs per bale		Total costs per bale	
	$1.00 per hour	$1.25 per hour	$1.00 per hour	$1.25 per hour	$1.00 per hour	$1.25 per hour
Bales	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
			Area I			
6,000	12.45	12.65	2.33	2.33	14.78	14.98
7,000	11.45	11.60	2.00	2.00	13.45	13.60
8,000	10.70	10.90	1.75	1.75	12.45	12.65
9,000	10.20	10.35	1.55	1.55	11.75	11.90
10,000	9.70	9.85	1.40	1.40	11.10	11.25
11,000	9.30	9.45	1.27	1.27	10.57	10.72
12,000	9.00	9.15	1.16	1.16	10.16	10.31
13,000	8.70	8.85	1.08	1.08	9.78	9.93
14,000	8.45	8.60	1.00	1.00	9.45	9.60
15,000	8.25	8.40	.93	.93	9.18	9.33
16,000	8.10	8.25	.87	.87	8.97	9.12
17,000	7.95	8.10	.82	.82	8.77	8.92
18,000	7.80	8.00	.79	.79	8.59	8.79
19,000	7.65	7.90	.77	.77	8.45	8.67
20,000	7.58	7.80	.75	.75	8.33	8.55
21,000	7.48	7.70	.74	.75	8.22	8.45
			Area II			
6,000	14.30	14.60	2.33	2.33	16.63	16.93
7,000	13.00	13.20	2.00	2.00	15.00	15.20
8,000	12.10	12.25	1.75	1.75	13.85	14.00
9,000	11.40	11.60	1.55	1.55	12.95	13.15
10,000	10.80	10.90	1.40	1.40	12.20	12.30
11,000	10.30	10.45	1.27	1.27	11.57	11.72
12,000	9.90	10.05	1.16	1.16	11.06	11.21
13,000	9.55	9.70	1.08	1.08	10.63	10.78
14,000	8.25	9.40	1.00	1.00	9.25	10.40
15,000	9.00	9.15	.93	.93	9.93	10.08
16,000	8.75	8.90	.87	.87	9.62	9.77
17,000	8.60	8.75	.82	.82	9.42	9.57
18,000	8.35	8.60	.79	.79	9.14	9.39
19,000	8.30	8.50	.77	.77	9.07	9.27
20,000	8.18	8.35	.75	.75	8.93	9.10
21,000	8.02	8.20	.74	.75	8.76	8.95

Cost Comparisons

Per bale cost comparisons between model gins achieving equal annual volumes by the storage method and by increasing the gin plant capacity are shown in Figure 8. For all three gin sizes the costs associated with gins achieving added volume through seed cotton storage are higher than costs for a gin achieving this volume by increasing the capacity of the gin plant.

The immediate implication of this cost comparison would indicate that it would not pay a ginner to attempt to increase his capacity through the basket storage method. This conclusion would be justified in the case of a ginner deciding between alternatives if he did not already have "sunk" costs in a gin which could still be used. In terms of ginners' long-run planning horizon these cost comparisons should give some insight on how to look at the future.

While not equally applicable to all ginners, the cost differences illustrated in Figure 8 may be less than it would appear. It is generally recognized among ginners who furnish their customers with cotton trailers that the gin could operate with substantially fewer trailers if a

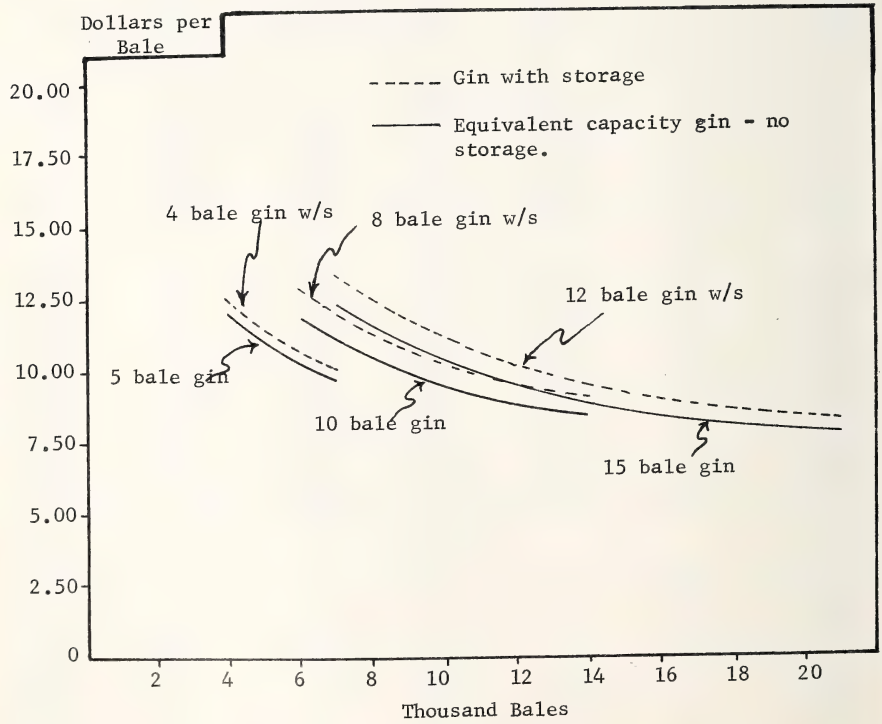

FIGURE 8.—Relation of Average Ginning Costs to Two Methods of Obtaining Increased Annual Volumes—Increased Gin Capacity and Seed Cotton Storage—Three Different Size Gins, Area I, $1.00 per Hour Wage Rate, Louisiana, 1961-62.

basket storage system were utilized. Faster return of trailers to the field would reduce the number needed. As an illustration, a ginner operating an 8-bale-per-hour gin and ginning approximately 8,000 bales annually might now own 40 cotton trailers which he furnishes at no cost to his customers. By installing a basket storage system he might be able to operate his gin satisfactorily by providing only 10 trailers to his customers. On the basis of the fixed cost estimates shown in Table 8 this would result in a saving of approximately 29¢ per bale. Even greater savings would be achieved if repair and tire costs were considered, in addition to the elimination of a considerable headache in managing trailers.

The evidence presented thus far tends to indicate that a ginner contemplating the long-run situation would do well to plan a gin large enough to handle his anticipated volume without resorting to a storage system such as described and analyzed in this study. However, gin storage of seed cotton appears to have considerable merit for the ginner with "sunk" costs in a serviceable, low-capacity gin. In the short-run, as long as this ginner is meeting his variable costs and contributing something towards his fixed costs, he will maximize returns or minimize losses by continuing to operate the gin. If he can increase his volume by a storage system and in doing so contribute more to his fixed costs within the gin, it would pay him to do so. Thus, while it may be perfectly logical in the long-run to make cost comparisons between new gins as shown in Figure 8, in the short-run these cost comparisons should be made by excluding those fixed costs associated with an existing gin using a storage system.

Cost data suitable for making cost comparisons between discrete sizes of older gins utilizing seed cotton storage and new gins of comparable capacity are not available. However, on the basis of evidence already presented in this study relevant to the substantial influence of fixed costs on total average costs of ginning, it would appear that ginners with "sunk" investment costs in a usable gin could increase volume through the storage method at lower costs than they could by investing in a new, larger capacity gin.

An alternative method of increasing gin capacity available to ginners who already have a serviceable gin of limited capacity is to add one or two additional stands to the existing facility. Usually the cost of the additional gin stands is only a part of the total cost associated with increasing capacity in this manner. The total cost depends on what other equipment in the gin requires alteration or replacement to handle the increased volume. Ginners selecting this method of increasing capacity often encounter relatively high operating costs because of inefficient gin layouts and bottlenecks. No empirical data on this method of increasing gin capacity are available on which to make cost comparisons with the methods analyzed in this study.

Institutional Barriers to Storage

It is beyond the scope of this study to do a thorough analysis of the institutional barriers to establishing a seed cotton storage system at a cotton gin. The best that can be hoped for is to acquaint the reader with some of the problems which must be faced in changing a well-established system of behavior patterns.

The comparative analysis in this section has, for the most part, ignored these institutional barriers. While not identifying them by this name, ginners are generally aware of their existence. When the idea of seed cotton storage is advanced, many ginners agree on the general merits of the system but are quick to point out areas where customer resistance would be encountered.

Earlier in this section it was pointed out that seed cotton storage is not new. In earlier times seed cotton was harvested by hand labor at a more leisurely pace and held on the farm until a sufficient quantity was available to make a trip to the gin. The harvesting operation was spread over a much longer period; consequently, cotton arrived at the gin over a longer period of time in a distribution pattern which was less peaked than it is today. As a result, farmers were not required to wait excessively long periods to have their cotton ginned and sold.

The traditional desire to market cotton soon after harvesting is still prevalent among cotton farmers. Farmers usually need their money at this time to clear debts incurred during the production season. A storage system would necessitate further financing of the cotton crop until it was ginned and sold. An alternative to longer financing would be to sell or borrow on the seed cotton at some specified percent of its anticipated value while still in storage, subject to an adjustment when it was ginned. At present there is no acceptable method of grading seed cotton which would facilitate the sale of seed cotton prior to ginning, although some work is being done in this area.

Prior to the government loan and storage program price fluctuations were an important factor in cotton marketing and are still important to a limited extent. The question of who assumes the risk of price change during storage, while not as important as it once was, is still a factor which might inhibit customer acceptance of seed cotton storage at the gin. Hedging, which might offer a solution for large producers, does not appear promising for the small producer.

Costs associated with losses by fire during storage have been included in the cost estimates developed in this section. Losses resulting from quality deterioration during storage are another matter. Although the assumption was made earlier that cotton could be stored over time with no quality deterioration, it is conceivable that some quality damage could result from storing excessively wet cotton or leaving it in storage for excessive lengths of time. The assumption that seed cotton was storable was based on the prudent exercise of judgment and the use of a moisture meter by the ginner. If the ginner neglects to exercise this prudence, quality damage to the cotton could result. The determination of who will bear the burden of this loss and what criteria will be used in determining what the quality of the cotton was before damage from storage are questions which remain unanswered.

AN APPLICATION OF THE MODEL

The combined assembly and ginning average cost curve discussed and illustrated earlier is materially influenced by the density of cotton production in the area from which the gin draws cotton. A ginner seeking information on which to base rational economic decisions must be cognizant of the amount of cotton in his area and how he would have to extend his supply area with a given increase in annual volume ginned. To apply the model gin and assembly costs developed in this study to his own situation he must have some idea of the location and density of cotton production in his anticipated supply area.

Source of Production Density Data

Cotton production density data were obtained for the 12 parishes under study from the state and parish offices of the Agricultural Stabilization and Conservation Committees. Each farm history card was examined to determine if the farm had a cotton allotment. If it did, the 1960 allotment acreage was recorded by aerial photograph number. Allotment acreages were then summarized for each aerial photograph and the number of square miles on each photogrpah computed. The cotton density per square mile was computed and this information was then transferred to parish road maps. This method pinpointed cotton production within an area approximately 2½ miles square, depending on the area covered by the aerial photograph. This appears to be the most precise method available to locate cotton production short of a complete enumeration. Because of the method used in constructing parish key maps for use with these aerial photographs, this method of locating cotton production density tends to bias the location slightly in a northeast direction. The amount of bias, however, was judged insufficient to affect the results of the study. The general patterns of cotton production density for Areas I and II are shown in Figures 9 and 10.

Tensas Parish — An Example

The purpose of this section is to show an application of the model gin cost data and assembly cost data to a limited area in the state. It is hoped that it will provide ginners with a logical approach to the application of these data to their own situation for planning purposes.

Tensas Parish was selected because there appeared to be a minimum of inter-parish hauling of seed cotton and because of the relatively

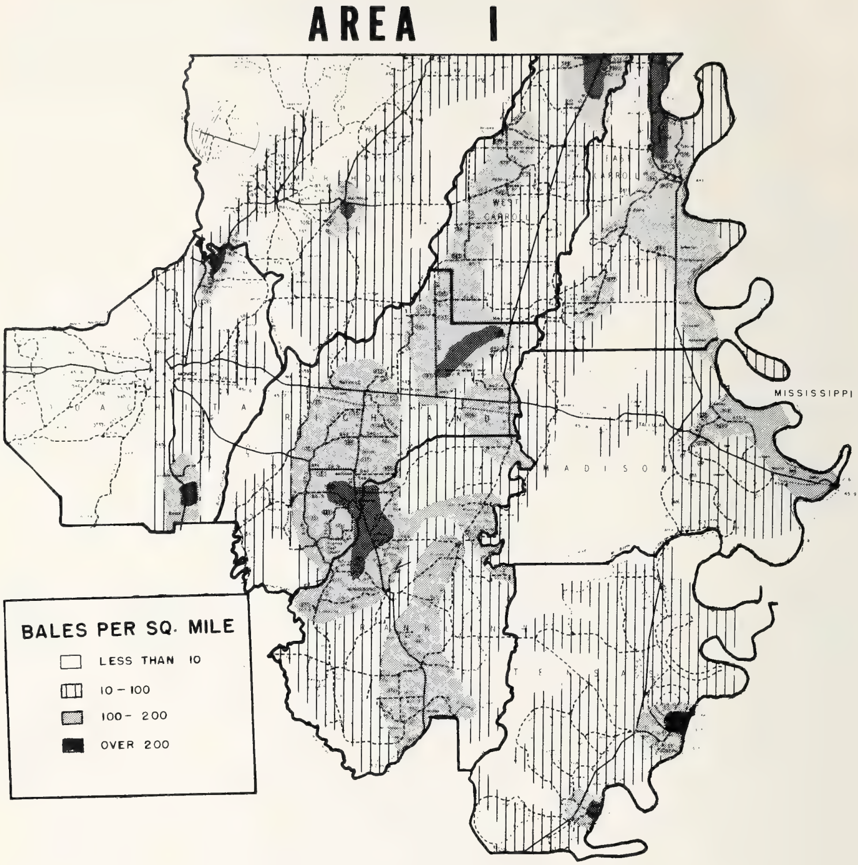

FIGURE 9.—Cotton Production Density, Area I, Louisiana, 1960.

uniform density of cotton production throughout the parish. A minimum of inter-parish hauling of seed cotton insured that all or most of the cotton produced in the parish was ginned within the parish.[18]

One of the first steps a ginner should consider is to define his supply area. In the sample used, Tensas Parish, this step involves first considering the natural boundaries or barriers to cross-hauling of seed cotton.

Tensas Parish is bordered on the east by the Mississippi River, with the nearest bridge well beyond the usually accepted hauling distance for seed cotton. The western boundary of the parish is formed by the Tensas River and Big Roaring Bayou, with only one road crossing. To the north

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[18] It should be pointed out that this section is simply an example of the steps and factors a ginner might consider in predicting the long-run equilibrium situation in his own area. The long-run equilibrium situation posed for Tensas Parish is only one of several possible alternative situations which might develop in that parish.

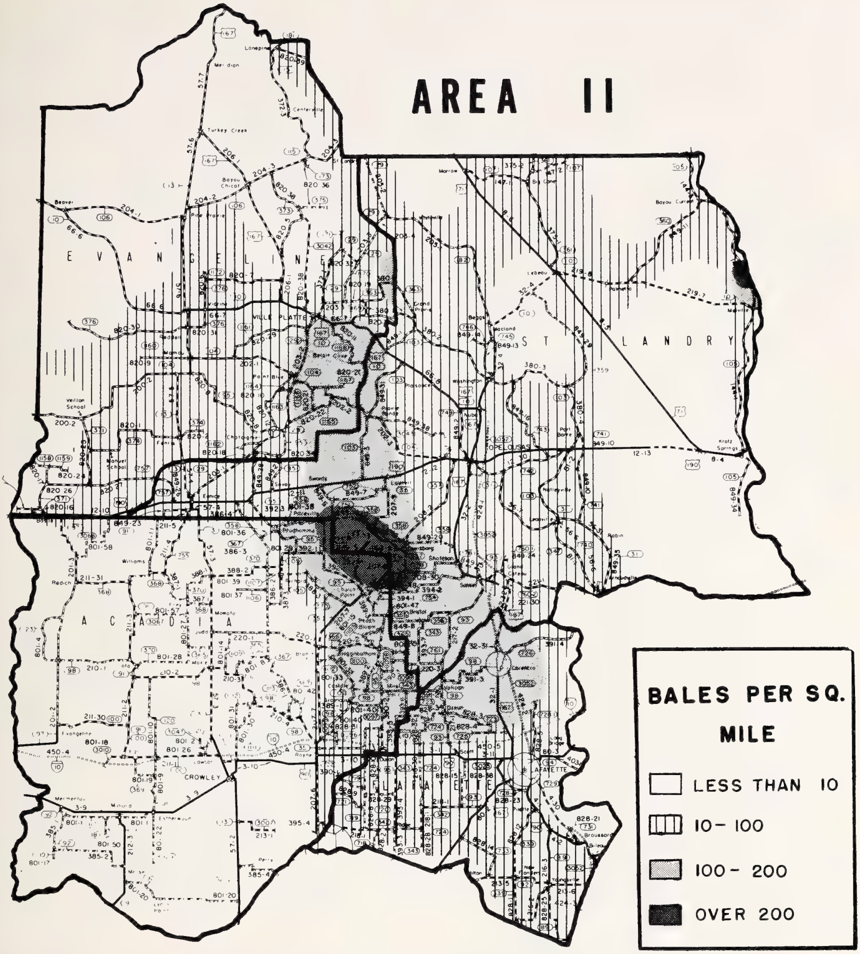

FIGURE 10.—Cotton Production Density, Area II, Louisiana, 1960.

the parish is bounded by the Tensas River, Mill Bayou, and Bayou Vidal, with two road crossings. The southern boundary of Tensas Parish is formed by Concordia Parish and is only nine miles long. Three roads provide cross-parish movement in this direction. The principal barriers to cross-hauling of seed cotton are the Mississippi River to the east and the Tensas River to the north and west. Some cotton is believed to move south into Concordia Parish to a gin in Clayton, but a large part of this is offset by an inflow of cotton from Concordia Parish.

At present there are six gins in the parish—two at Waterproof, two at St. Joseph, and two at Newellton (see Figure 11). The combined hourly capacity of all six gins is estimated to be slightly less than 50 bales per hour. On the basis of the same procedure used previously to estimate capacity, these six gins have an annual capacity of about 71 thousand bales. The production in Tensas Parish was 18.7 thousand bales in 1961, and 23.6 thousand bales in 1960.[19] The average production for the 10-year period 1952 to 1961 was 23.4 thousand bales. Hence, production averaged about one-third of the available gin capacity.

Tensas Parish contains a land area of approximately 398.7 thousand acres, or about 623 square miles.[20] Of this area 61.5 percent is in farms. The bulk of the land not in farms is on the western and northern borders of the parish. The Chicago Mill and Lumber Company has large timber holdings in this area. On a parish-wide basis the average density of cotton production is 37.5 bales per square mile, and on the basis of land in farms, 61.0 bales per square mile. Only in a few isolated areas does cotton production exceed the range of 10 to 100 bales per square mile. For this reason the assumption of a uniform density of 50 bales per square mile appears reasonable. The location and density of cotton production in Tensas Parish is shown in Figure 11.

In locating gin facilities in Tensas Parish consistent with the cost estimates developed in this study, it would appear most economical from an industry standpoint to establish one gin in the parish capable of handling the entire crop. If this gin were centrally located in the parish, hauling distances of 20 to 25 miles would be involved. Earlier studies of the average distance farmers hauled cotton have generally indicated that farmers tend to resist hauling cotton more than 10 miles, with the average haul being around 5 or 6 miles. This limit has probably increased somewhat in the past 10 years as gins have decreased in number and transportation facilities have improved.

As a result of expected farmer resistance to long hauling distances, a number of factors other than costs should be considered when locating optimum ginning facilities in an area. The most important of these factors are:

1. Ginning facilities should be located with easy access to a paved road and a railroad.
2. Consideration should be given to the accessibility of compresses, warehouses, and oil mills.
3. Cotton should not be hauled more than 12 air miles distance to the gin, or 30 to 45 minutes away from the gin.
4. Gin capacity should be sufficient to handle the crop in good years.

In the Tensas Parish example, two gin locations were selected as most nearly meeting the above criteria (see Figure 11). Concentric circles were drawn around these two sites at 2-mile intervals to illustrate that most of the cotton in the parish falls within the 12-mile limit. Both gin

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[19] Louisiana Crop Reporting Service, *Louisiana Cotton: Acreage, Yield, and Production, 1952-61,* Alexandria, Louisiana.

[20] U.S. Department of Commerce, Bureau of the Census, *1959 Census of Agriculture - Preliminary, Tensas Parish, Louisiana,* November 1961.

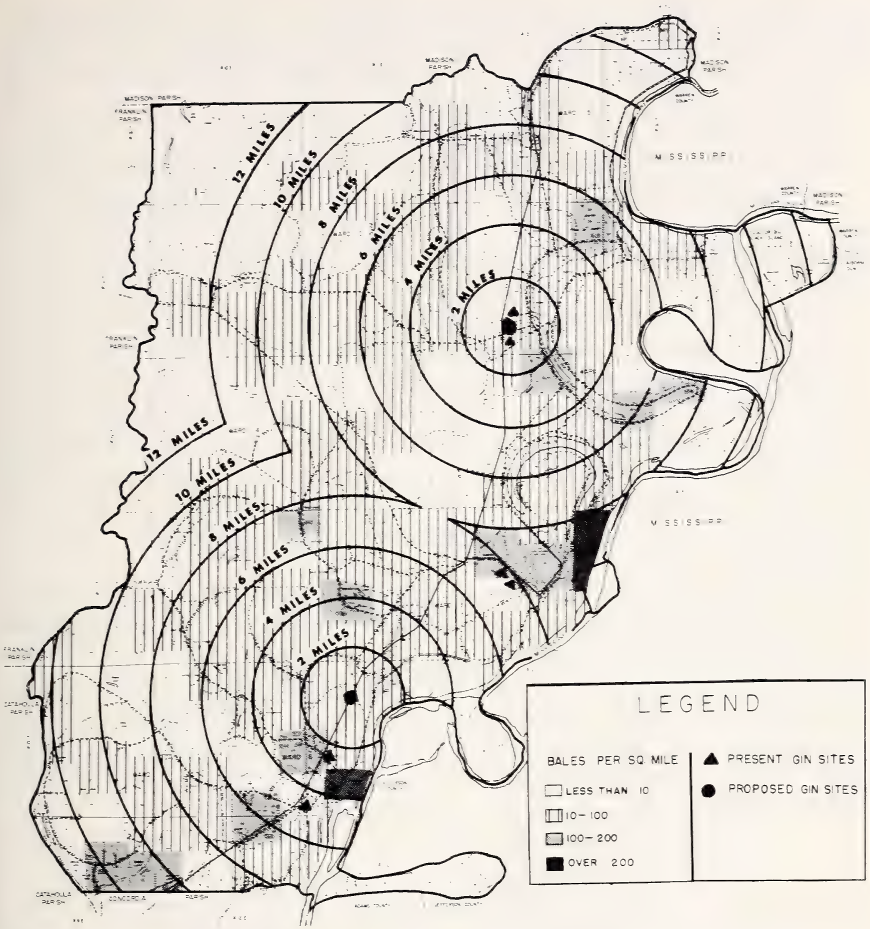

FIGURE 11.–1960 Cotton Production Density and Location of Present and Proposed Gin Facilities, Tensas Parish, Louisiana.

sites are located on a railroad and a paved highway. The Newellton site is near a warehouse which is also on the railroad. The Chamblee Spur site is located between the railroad and U.S. Highway 65. Both sites are equally accessible by direct highway or rail to warehouses and compresses in either direction at Ferriday and Tallulah. The warehouse and compress at Winnsboro is accessible to nearly any site in Tensas Parish by truck. Since the nearest oil mill is at Monroe and seed can be shipped either by truck or rail, this is not an important consideration in the location of gins in Tensas Parish.

Two 10-bale-per-hour gins, each with an annual capacity of more than 14 thousand bales, would provide ample ginning capacity to handle the crop with the limits of the distribution shown in Figure 3. This would provide sufficient excess capacity to handle the crop in the years of high production. Figure 11 indicates that the Newellton gin may have slightly more cotton available than the other site. However, this difference does not appear sufficient to call for a larger gin at this site.

If the costs illustrated in Figure 5 are used, this example would provide ginning costs of approximately $9.00 per bale. The combined costs of assembly and ginning, as shown in Figure 7, would be about $11.50 per bale. This compares with current ginning charges of $2.25 per 100 pounds of lint, plus $5.00 for bagging and ties, or $16.25 for a 500-pound bale.

There are other possible alternatives to the gin locations posed in this section. However, the locations selected appear to satisfy quite well the locational criteria established earlier for this example. One factor not mentioned but of some importance in reducing ginning costs is the accessibility of a natural gas supply. The use of natural gas for drying can result in savings of 30 to 40 cents per bale over the use of butane. No general information was available on the location of natural gas lines in Tensas Parish; however, natural gas was available at both of the proposed sites.

It is not the purpose of this study to suggest that those gins in Tensas Parish which do not fit the criteria for gin locations suggested should be shut down and new gins established at the proposed sites. Rather, the purpose is to illustrate in a somewhat detached, objective manner a method by which ginners can analyze and predict the long-run equilibrium situation in their area. A ginner contemplating the future is well advised to keep in mind that for some years to come he will have to share his supply area with other gins.

Applicability to Other Areas

Tensas Parish was selected to illustrate the application of the model gin structure and is meant to serve only as an example. Admittedly this parish presented fewer problems than could be expected in other areas. Tensas Parish was treated in isolation because production and other data are published on a parish basis. It is conceivable, however, where physical barriers to inter-parish movements of seed cotton do not exist, that model applications would encompass two or perhaps more parishes.

The application of the model to other locations could be undertaken in a manner quite similar to that used in Tensas Parish. If the area were one in which cotton production was not expected to maintain its competitive position, such as Area II in this study, model gin cost estimates would of necessity reflect the shorter depreciation period and, hence, higher ginning costs. The weighting of various criteria used in selecting gin sites will probably vary between different areas. For example, suppose a warehouse and compress were located in the production area under consideration, although not adjacent to the ideal gin site from a distance standpoint. The economies associated with locating the gin adjacent to the warehouse and compress might be sufficient to overcome the general reluctance of farmers to haul cotton more than 10 to 12 miles. Lower ginning charges which reflect these efficiencies would be the economic incentive necessary in motivating farmers to haul their cotton farther.

In the application of the model to any area, economies of size within the gin tend to be greater than added assembly costs. However, these economies do not motivate farmers to haul cotton greater distances unless they are reflected in lower ginning charges. At the present time in Louisiana the reluctance of ginners to depart from uniform ginning charges tends to preserve the status quo. This reluctance to engage in price competition accounts in large measure for the slow progress toward the eventual situation postulated in this study, i.e., fewer and larger gins in the state.

SUMMARY AND CONCLUSIONS

The primary purpose of this study was to provide ginners with some insight into the conflicting situation facing them in the area of economic planning. Ginners are faced with a paradoxical situation in which excess gin capacity is generally accepted as the prevailing situation throughout the Cotton Belt, while at the same time they are often unable to gin cotton as rapidly as their customers demand. A secondary objective was to investigate per unit cost reductions associated with volume and to study the relation of ginning costs to size of gin plant, or scale. Assembly costs were included in the analysis because with increasing gin size, cotton must be assembled over increasing distance at increasing costs. Assembly cost estimates were made for four levels of production density and combined with model gin cost estimates to illustrate what appears to be the economic prospects of the cotton ginning industry in Louisiana. Guides to the use of the study findings by ginners in their quest for lower ginning costs and movement toward long-run equilibrium were provided by applying the model to a limited area of Louisiana.

Two areas in the state were selected for study, primarily to demonstrate the diversity of cotton production prospects facing ginners in the state. The first area was one in which cotton was expected to maintain its competitive position. The second area was one in which cotton was expected to continue to decline in importance. Normal depreciation and debt amortization schedules were the expected outlook in the first area, while relatively shorter depreciation and debt repayment schedules were expected in the second area. Because of faster debt retirement, ginning costs would be expected to be higher in the second area.

Average cost estimates were developed for gins with capacities of

4, 8, 12, and 15 bales per hour. Gins were assumed to operate at several levels of annual volume measured in hours of operation. These levels were arbitrarily set at 600, 800, 1,000, 1,200, 1,400, and 1,700 hours annually.

Gin cost estimates were made for the two production areas by using a quasi-synthetic or a modified economic-engineering approach. The method used departs from a pure economic-engineering approach to the generation of cost data, because it involved studying investment and operating costs of four new, all-electric cotton gins of different sizes located in Louisiana. Adjustments were made in the cost structure of these four gins when costs did not appear reasonable or where it was ascertained that difficulties were encountered during the first year of operation. Two levels of hourly wages for gin labor were used in making cost estimates for the two production areas previously discussed. Although a wage rate of $1.00 per hour generally reflected conditions in Louisiana, a wage rate of $1.25 per hour was used in anticipation of rising wages and the possibility of gin labor eventually coming under the provisions of minimum wage laws. These two hourly wage rates resulted in different ginning costs ranging from 25¢ per bale in the 4-bale-per-hour gin to 17¢ per bale in the 15-bale-per-hour gin.

Average Ginning Costs

Average gin cost estimates for the four gin sizes analyzed continued to decline well beyond the largest volume encountered by any gin in Louisiana. This indicates that, provided sufficient cotton is available, the larger the gin, the lower are ginning costs per bale. For example, when the four model gins are operated for 1,700 hours annually in Area I, assuming a wage rate of $1.00 per hour, the costs per bale are $9.86 for the 4-bale gin, $8.76 for the 8-bale gin, $7.90 for the 12-bale gin, and $7.61 for the 15-bale gin. This is a 23 percent decrease in costs from the 4-bale-per-hour gin to the 15-bale-per-hour gin. The percentage reductions in costs are even greater when the gins are used at less than annual capacity. For example, when the gins are operated for 600 hours annually, the reduction in cost from a 4-bale gin to a 15-bale gin is $16.58 per bale to $11.76 per bale, a reduction of 29 percent.

Economies of Scale

Economies of scale in cotton gins were demonstrated by holding the number of hours of annual operation constant and varying the gin size. Three aspects of these scale relations appear significant.

(1) As plant size is increased, average unit costs decrease rapidly from a 4-bale to an 8-bale-per-hour gin and then at a less rapid rate as gin size is increased further. For example, when gins are operated 600 hours annually, per unit costs drop $2.61 as gin size is increased from

4 bales per hour to 8 bales per hour, but only 55¢ when gin size is increased from 12 bales per hour to 15 bales per hour.

(2) Average unit costs decrease substantially as the annual utilization of the plant is increased. For example, when a 4-bale-per-hour plant is utilized for only 600 hours, costs are $16.58 per bale, but only $9.86 per bale when the same plant is operated 1,700 hours.

(3) The magnitude of scale economies decreases as the annual hours of operation increase. For example, the reduction in costs for a 4-bale gin operated for 600 and 1,700 hours is from $16.58 per bale to $9.86 per bale, a reduction of $6.72. The reduction in costs for a 15-bale gin operated for 600 and 1,700 hours is from $11.76 per bale to $7.61 per bale, a reduction of only $4.15 per bale.

Assembly Costs

Underlying all gin cost models was the assumption that cotton arrived at the gin in some definable pattern. The average distribution of seed cotton receipts at gins during the 10-year period 1950-1959 was the distribution used in this study. Annual gin capacities were determined primarily on the basis of this assumed distribution of cotton arrivals at gins. While this distribution is an average and does not reflect the wide differences in year to year harvesting patterns, its use appears considerably more reasonable than cotton receipts during any single year.

Costs associated with the movement of seed cotton from the field to the gin were estimated from data obtained by personal interview with cotton producers and custom harvesters. The most common method of moving cotton from the field to the gin was found to be a pickup truck pulling a 5-bale cotton trailer. Investment and operating costs were estimated and average assembly costs computed for four levels of cotton production density. On the basis of data obtained from the Louisiana Agricultural Stabilization and Conservation Committee, densities of 50, 100, 200, and 300 bales per square mile were found to embrace nearly all production in the two areas studied. Average cost curves indicate that assembly costs per bale increase with distance from the gin, but at a decreasing rate for all densities of production considered. For example, at a density of 50 bales per square mile, a 1,000-bale increase in the amount of cotton available to the gin, from 2,000 to 3,000 bales, increases average assembly costs 22¢ per bale. A similar increase from 29,000 to 30,000 bales only increases average assembly costs 6¢ per bale.

Since the alternative of increasing the volume of cotton processed in a gin by increasing the intensity of production in the existing supply area is severely limited by the acreage control program and the patterns of technological adoption, the volume of cotton handled annually by a gin can be increased most effectively by increasing the size of the supply area. Consequently, distance hauled and, thus, assembly costs per bale increase in the manner indicated earlier. Economies associated with increasing gin size must, therefore, be examined in combination with the dis-economies of increasing assembly costs.

Combined Assembly and Ginning Costs

Assembly costs are usually borne by the cotton producer and not the ginner. This study, however, is concerned with the combined assembly and ginning cost to the industry as a guide to achieving the industry goal of more efficient cotton marketing. Average assembly costs per bale were added to average ginning costs per bale to obtain a combined average cost for the two operations. Since ginning costs decrease with increases in volume and assembly costs increase, the shape of the combined cost curve depends on the relative influence of its individual parts. In this case, economies within the gin are greater than added costs of assembly, and the combined average cost curve continues to decline over the entire range of volumes considered. For example, combined assembly and ginning costs for a 4-bale gin in Area I, with an assumed wage rate of $1.00 per hour and a production density of 50 bales per square mile, decrease from $17.90 per bale at an annual volume of 2,000 bales to $11.65 per bale at an annual volume of 6,000 bales. This is a 35 percent reduction. Similarly, combined assembly and ginning costs for a 15-bale gin operating under the same conditions decrease from $14.37 per bale at an annual volume of 7,000 bales to $10.90 per bale at an annual volume of 22,000 bales. This decrease represents a 24 percent reduction in the combined costs. The combined cost curves decline less rapidly than the ginning cost curves alone because of the influence of increasing assembly costs. In the two examples just cited, the combined costs decreased 35 percent and 24 percent. When ginning costs alone are considered under the same conditions, costs decrease 42 percent and 38 percent, respectively.

Seed Cotton Storage

As an alternative to increasing annual volume by enlarging the capacity of the gin, cost data were developed for a basket storage system designed to increase gin capacity by extending the period during which the gin could operate. Cost estimates were developed in the same manner utilized in estimating model gin costs. Costs for the storage system were then integrated into the gin cost structure and cost comparisons made between the gin-storage method of achieving a given annual capacity and a new gin with equivalent annual capacity. These comparisons indicate that when only new gins are considered (that is, a new gin with a storage system versus a new gin of equivalent annual capacity without storage), lower ginning costs per bale result when the initial investment is made in a gin plant sufficiently large to handle the anticipated volume without storage. For example, the average difference in costs between the two methods was about 51¢ per bale higher for a new 4-bale gin with storage than for a new 5-bale gin and about 70¢ per bale higher for a new 12-bale gin with storage than for a new 15-bale gin.

Most ginners, however, are faced with a situation where they have to consider costs already "sunk" in an existing gin. No empirical data were available for making comparisons between old gins of varying size with a storage system and new gins of equivalent capacity. However, the omission of heavy fixed investment costs from the old gin side of the comparison may suggest that ginners owning existing facilities would do well to investigate a storage system before investing in a new gin.

The analysis of seed cotton storage generally ignored the effects of certain institutional barriers to storage. While it was beyond the scope of this study to investigate these barriers, it did appear useful to discuss them briefly so that ginners might anticipate areas of possible resistance or where substitution of other institutional arrangements might be necessary.

Application of the Study Findings

The usefulness of the model developed in this study will be determined when ginners attempt to apply it to their own situation. As a guide to its application, one area—Tensas Parish—was selected to illustrate the way a ginner might proceed in determining the long-run equilibrium position of his parish. Certain criteria were established for the location of gin sites. Because of farmer resistance to hauling cotton relatively long distances and because production in the parish would exceed the capacity of a 15-bale-per-hour gin, two 10-bale-per-hour gins appeared to constitute the optimum situation. Cost estimates developed herein indicate that in this situation ginning costs would be approximately $9.00 per bale and combined assembly and ginning costs approximately $11.50 per bale, as compared to current ginning charges of $16.25 per 500-pound bale.

When applied in other areas, the suggested locational criteria may be weighted in a somewhat different manner. That is, one requirement may be deemphasizd in order to meet another requirement which has greater economic importance. Problems of this kind, however, must be judged at the time and place in which they occur. Despite the uniqueness of each situation, it is felt that the general procedure presented herein provides ginners with a systematic, if not "pat," approach to analyzing future trends and reducing ginning costs.

Implications

The implications for ginners appear rather clear-cut. Economies of scale within gin plants which are not offset by increasing assembly costs, at least not at volumes generally considered feasible today, indicate that in the long-run the Louisiana cotton industry is likely to continue moving toward fewer and larger cotton gins. Thus, there are sound economic reasons for this trend which has been evident since 1915.

Cost comparisons indicate that, in the case of a ginner considering the alternative of a new gin with storage as opposed to a new gin of equivalent capacity without storage, lower unit costs will be realized if the investment is made in a gin of sufficient capacity to handle anticipated cotton receipts without resorting to storage. For a ginner wishing to increase capacity but faced with a "sunk" investment in a serviceable gin, investment in a storage system may be the least-cost, short-run method of achieving this additional capacity.

This study has generally demonstrated that ginners can achieve lower ginning costs by several alternative methods. First, reduced per unit costs were demonstrated through economies of scale. That is, lower ginning costs were associated with the modern, large, high-capacity gins.

Second, and closely tied to economies of scale, are the per unit cost reductions which can be achieved with larger annual ginning volumes. Naturally, economies of scale are achieved only through larger plants and the ensuing larger annual volumes. However, because of heavy fixed operating costs, significant unit cost reductions can be achieved via the volume route by ginners with an investment in gin facilities that are somewhat less modern than the gin models considered in this study.

Third, this study demonstrated that, within certain limits, the costs of assembling additional volumes of cotton over a widening supply area are not sufficiently large to offset the resulting per unit cost reductions which occur in the gin. Consequently, ginners need to examine their ginning charges rather carefully as a means to achieving added volume. By passing some of these economies on to the producer in the form of lower ginning charges, the resulting additional volume may produce greater total profits.

Finally, seed cotton storage may provide the short-run, least-cost solution to the ginner with a serviceable gin who desires to increase volume beyond the present annual capacity of his gin. This alternative should only be considered as a short-run solution because the storage facility, being new, will probably last longer than the existing gin plant. However, a storage system may provide the method whereby the gin can be utilized over a longer period of time.

APPENDIX A

THE NATURE OF GIN COSTS

Cotton ginning costs can be divided into the two conventional categories, fixed and variable. Buildings and equipment depreciation, taxes, and insurance fall in the first category, while labor, bagging and ties, power and drier fuel, and other operating expenses fall in the latter. There are, however, some cost items used in ginning cotton which have both fixed and variable characteristics. These are sometimes referred to as overhead costs. The classification of these costs into either the fixed or variable category is usually based on the degree to which they resemble one or the other. Admittedly, such a selection becomes highly arbitrary at times.

Fixed Costs

Depreciation

Equipment or machinery depreciation costs are fixed to the extent that machinery depreciates in value or becomes obsolete over time irrespective of use. Hence, certain portions of machinery depreciation costs are incurred even if no production takes place. Technological obsolescence in recent years has been extremely great in cotton gin equipment and, as a result, this appears to be a significant part of depreciation costs in cotton gins.

Certain problems are encountered in determining a reasonable useful life estimate to use in computing depreciation costs of machinery. Most cotton gin equipment manufactured today will, with reasonable maintenance and care, last at least 20 years. On the other hand, rapid strides currently being made in the design improvement of gin equipment makes most of this equipment out-of-date long before it has worn out. Competition being what it is in the gin industry, a ginner wishing to maintain or expand his present volume cannot expect to get the full life out of a machine before being forced by technological obsolescence to invest in newer, improved models. In addition to this, if the situation in an area is one in which the prospects for cotton production are not very bright, the amortization period necessary to attract investment capital becomes extremely short.

Depreciation costs of gin buildings follow much the same pattern as equipment depreciation costs. To a lesser degree the same type of technological obsolescence encountered with gin machinery is encountered with gin buildings. Ginners attempting to modernize older gins frequently find the old building inadequate to house the new equipment even though it is not worn out. Use of the old building frequently adds substantial amounts to investment costs for alterations as well as contributing to increased ginning costs through inefficient gin lay-outs.

Gin buildings of noncombustible material can be expected to last

40 to 50 years with proper care. Again, however, the realities of the current ginning industry make a shorter period for depreciation more reasonable. In an area of declining cotton production the period becomes even shorter.

Most ginners find it necessary to have a tractor or a truck available on the gin yard to move trailers around. In reality most ginners use a tractor which is available from one of their other enterprises, and no costs, except on occasion fuel and oil, are charged to the ginning operation. However, if the gin operation is to stand alone, some charge must be made for the use of a tractor or truck.

Interest on Investment

The interest on investment in gin buildings and equipment represents a return to capital and must be covered in the long-run if the firm is to survive.[21] It seems logical that if the capital necessary to build a new gin had to be borrowed, the payment of interest on this money is necessary to remain in business. If the owner had already accumulated the necessary capital and invested it in a cotton gin, he would have to give up a nominal return or income from this capital. Consequently, his income will be reduced by an amount perhaps equivalent to what he would have to pay in interest had he borrowed the investment capital. While a ginner possessing the capital necessary to build a gin may be willing to take a smaller return on his capital than it would cost to borrow it, cost comparisons between gins make it necessary to adopt a relatively uniform cost of financing the business.

Insurance

Fire and comprehensive insurance on the gin buildings and equipment is usually considered as a fixed cost item of expense in gin cost studies. Although insurance coverage is not absolutely necessary if the gin does not operate, where borrowed capital is involved lenders usually insist on adequate coverage. Where the owner does his own financing, prudent management practices dictate at least some degree of protection of the capital investment.

Taxes

There appears to be little doubt that ad valorem taxes display fixed cost characteristics. Tax rates between communities and parishes vary widely. The percentage of market value at which assessments are set varies widely between parishes and communities, as do the millage rates on assessed valuation. During 1958, ratios ranged from 31.5 to 7.1 percent of current market value, and millage rates varied from 76.3 to 20.8 mills per dollar of assessed value.[22]

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[21] Tibor Scitovsky, *Welfare and Competition, The Economics of a Fully Employed Economy* (Chicago: Richard D. Irwin, Inc., 1951), pp. 201-202.

[22] Public Affairs Research Council of Louisiana, Inc., *The Property Tax System of Louisiana, Volume I, General Findings* (Baton Rouge, Louisiana, October, 1960), p. 173.

Management and Office Salaries

Both management and office salaries represent items of costs which display some of the characteristics of both fixed and variable costs. Neither a manager nor a bookkeeper is necessary if the firm does not operate, but once the decision is made to operate, their salaries become a fixed operating cost over a wide latitude of volumes. Since most cost analyses of firms are based on the assumption that the firm is operating, these costs are usually considered to be fixed.

These items of fixed costs play an important role in determining the survival of cotton gins over time. Heavy fixed costs can be recovered only if the gin is able to obtain sufficient volume to spread these costs over a large number of bales. The larger the number of bales, the lower fixed costs will be per bale and the more likely ginning revenues will cover them.

Variable Costs

Those costs which vary directly with volume are known as variable costs. Ginning costs which exhibit this direct relationship are: labor, bagging and ties, electric power, drier fuel, yard insurance, and other operating expenses.

Labor

Labor expenses per bale usually decline with increased volume as labor is utilized more efficiently. The decline is more pronounced with volume increases in the lower, as compared to the higher, volume ranges. As the gin approaches capacity the labor costs per bale can be expected to level out and be practically constant.

The introduction of high-speed gin stands and other high-capacity equipment in cotton gins has brought about significant reductions in labor costs per bale. In many cases ginners have doubled volume with the addition of only one man to the gin crew. Labor costs in Louisiana of one dollar per bale, unheard of five years ago, are now occurring with regular frequency in new, high-capacity gins.

Bagging and Ties

The cost of bagging and ties per bale or pattern tends to be the same irrespective of the number of patterns used. Since bagging and ties are for all practical purposes a constant cost per pattern, and since most other per unit ginning costs tend to decrease with volume, the cost of bagging and ties becomes an increasing percentage of per bale costs as volume is increased.

Gin operators have little or no control over the cost of bagging and ties. Wide differences exist in the quality and weight of bagging used by cotton gins. Most ginners obtain their bagging and ties through the oil mill where they sell cottonseed. No evidence of volume discounts on bagging and ties was found among the ginners contacted in this study. Ginners have no alternative other than to pass the cost of bagging and ties on to their customers. Most gins made a specific charge for bagging and ties, while a few included them in a flat ginning charge per 500-pound bale of lint.

Electric Power

The number of all-electric cotton gins in Louisiana is quite small and limited almost entirely to relatively new gins, less than 5 years old. The majority of gins in Louisiana are powered by internal combustion engines using liquid petroleum gas or natural gas. Previous gin studies indicate that electric power usually costs more per bale than other sources of gin power. Despite this, the trend appears to be in the direction of all-electric gins with each piece of equipment individually powered.

Higher power costs per bale in electric gins do not tell the entire story. Ginners with all-electric plants contend that the added convenience, reduced maintenance, increased repair flexibility, and reduced labor requirements tend to offset, at least in part, the difference in costs. The elimination of line shafts, long belts, and complicated drive assemblies was considered a significant economy by these ginners. Other ginners argue that the elimination of belt adjustments brought on by temperature changes materially reduces labor costs.

Except at very low volumes, where minimum charges are encountered, volume ginned is not a major factor in electric power costs. Once the lowest kilowatt rate is reached, the costs per bale will tend to be constant.

The degree to which electric power costs per bale are lowered with volume depends in large measure on the rate structure under which the gin buys electric power. If the rate structure is based on a yearly volume of bales ginned, currently the case in much of Louisiana's cotton production area, most high-speed gins reach the lowest kilowatt rate relatively soon in the season. From this point on, power costs become almost constant. If, however, the rate structure is on the basis of kilowatts consumed per month, considerable economies are encountered in those months when volume is very high.

Drier Fuel

In 1962 the U.S.D.A. reported that 96 percent of all gins in the United States had seed cotton driers.[23] In Louisiana all of the newer gins are equipped with some type of drying equipment. Ordinarily the fuel used in Louisiana is natural gas, with some gins utilizing the more costly liquid petroleum gas when natural gas is not available at the gin site.

Natural gas costs for drying seed cotton tend to exhibit the same relation to volume ginned as electric power costs. Once the amount consumed has reached the least-cost rate, cost per bale tends to be constant.

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[23] USDA, Agricultural Marketing Service (AMS), Cotton Division, *Cotton Gin Equipment* (Memphis, Tennessee, 1962), p. 1.

Some variation in per bale drying costs will occur between individual lots of seed cotton, depending on the moisture content, and between wet and dry seasons.

Repairs and Maintenance

Repair and maintenance costs are defined as those costs associated with replacing worn and broken parts, routine oiling and greasing, and keeping the machinery in good working order. Costs associated with altering the gin are not included. Repairs and maintenance, as defined, are a function of volume of cotton ginned, the age of the machinery, the size of the plant, and the amount of foreign material in the seed cotton.

Annual repair and maintenance expenses for older gins are probably higher than repair expenses for new plants. The gins in this study were assumed to be new gins; consequently, the repair and maintenance expenses were less than would be expected for older gins. This, however, was offset by higher depreciation costs associated with the newer, more costly gin plants.

The assumption was made that the gin was equipped to handle spindle-picked cotton and conformed to the recommendations of the U.S.D.A., Stoneville Ginning Laboratory for delta conditions.

Insurance and Taxes

The insurance and taxes referred to in this section are distinct from those discussed earlier under fixed costs. Gin fire and comprehensive insurance and ad valorem taxes are fixed and decline rapidly on a per bale basis with increasing volume. Thus, the per bale costs at a volume of 3,000 bales are half as much as at a volume of 1,500 bales.

Certain other insurance costs and taxes are, however, related to volume in a direct fashion. Insurance which protects against losses on inventories of products owned by the gin or by customers, i.e., seed cotton, baled cotton, and cottonseed, falls into this category and is often referred to as "yard insurance" or "cotton products insurance." Not all ginners purchase this type of insurance, preferring to assume the risks themselves. In all probability this trend is the result of greatly reduced losses due to fires. The installation of CO_2 fire extinguishing systems in nearly all new gins, the use of all-metal machinery, the increase in machine-picked cotton, and the use of steel and concrete buildings probably account for this reduced fire loss.

Compensation insurance is considered a form of tax which varies with the payroll of the gin, and consequently, the volume ginned. This tax, which is really a function of volume, would most likely be relatively constant over most ranges of volume. Some decline might be expected if labor is assumed to be more efficient at larger volumes. Superior management might also contribute to a reduction in yard insurance if bale and cottonseed inventories were kept at a minimum by moving them on to the warehouse and oil mill. The location of a gin adjacent to a warehouse would reduce gin insurance costs but would increase insurance costs in the warehouse. A net savings would probably result from lower transportation costs and lower insurance rates in the warehouse.

Other Gin Expenses

Other gin expenses include items such as gin supplies, travel expenses, office supplies, telephone expenses, legal and audit fees, and miscellaneous expenses.

Gin Supplies — Gin supplies include small tools, oil and grease, belts, belt dressing, and numerous other small items necessary to the operation of a gin. These costs, while not particularly significant, vary to some extent with the volume of cotton ginned.

Travel Expenses — Travel expenses represent the cost of operating the ginner-manager's car or truck and other travel necessary in the conduct of the gin business. The variation in this cost item among gins is probably quite large since what constitutes gin business and what does not is subject to personal interpretation. For example, there would be no question concerning travel expenses incurred in rounding-up the gin trailers at the end of the season. Moreover, attending the annual ginners convention or ginners school might be considered a legitimate gin expense, but combining the trip with a vacation for the gin owner and his family might be questionable, at least in part.

Office Supplies — Office supplies are difficult to estimate since gin plants are usually part of a larger business and the offices are combined. These expenses include pencils, stationery, ink, postage, gin record books, bale tags, maintenance and repair of office machines, and various other minor items. These costs also vary to some degree with the volume ginned.

Telephone Expenses — Telephone expenses will vary depending on the extent of other business conducted from the gin office and the volume of cotton ginned. Any method used to separate those telephone expenses chargeable to the gin will be highly arbitrary.

Legal and Audit Fees — Legal and audit fees reflect, for the most part, an annual or monthly expense incurred by the gin to have an outside auditor prepare annual reports and summarize costs and receipts in a manner acceptable to the Internal Revenue Service.

Few ginners report any legal fees as a separate item of cost. In those cases where legal services are required in the building of a gin, this expense is usually capitalized into the cost of the gin. Since ginners ordinarily purchase cottonseed from their customers, this payment is applied toward the ginning charges. Usually the ginners seldom have any difficulty in collecting for ginning services. Very few legal fees are incurred in the collection of bad debts. In those rare cases when the cottonseed payment is not sufficient to cover ginning charges, ginners report it is extremely difficult to collect from customers. Most ginners simply write it off as a bad debt.

Miscellaneous Expenses — Minor items of expense are grouped under the heading of miscellaneous expenses more because of the small amounts than because of related purposes. These expenses include advertising and special customer services, donations to local charities, dues of the ginners association, and other minor expenses not categorized above.

THEORETICAL FRAMEWORK

The theoretical framework for this study of gin costs and efficiency involves modification and improvement of the conventional theory of production or theory of the firm.

Stages in Cotton Ginning

Ordinarily the operations within a plant are aggregated into different stages of production. Brems defines a stage as the aggregate of all units of a single durable factor employed by a plant (with or without nondurable factors cooperating with it).[24] French, Sammet, and Bressler broaden this definition to the extent that a stage consists of all productive services—durable and nondurable—that cooperate in performing a single operation on a group of minor but closely related operations.[25]

The stages involved in cotton ginning are best illustrated by a simplified plant process flow diagram (see Figure 12). Receipt of seed cotton is the first stage in the ginning operation. The over-all study involves two earlier stages outside the ginning operation—loading seed cotton and hauling to the gin. However, within the technical framework of the flow diagram in Figure 12, hauling would not be considered a separate stage but a flow or movement between the loading and receiving stages. Movement of the commodity between stages in any processing plant involves some form of transportation. This movement may be accomplished by conveyors, belts, fork-lift trucks, or any number of methods. In a cotton gin, seed cotton and lint cotton are moved through the various stages by large quantities of air, some of which is heated to accomplish the drying stages. During Stage 9 a by-product, cottonseed, is removed and flows in another direction. In some cases cottonseed is moved short distances by augers, but for the most part it too is moved by air. In Stage 12 another input item, bagging and ties, is fed into the flow.

In many processing plants temporary storage occurs between the

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[24] Hans Brems, "A Discontinuous Cost Function," *American Economic Review,* XLII, 1952, p. 577.

[25] B. C. French, L. L. Sammet, and R. G. Bressler, "Economic Efficiency in Plant Operations with Special Reference to the Marketing of California Pears," *Hilgardia,* XXIV, 1956, p. 545.

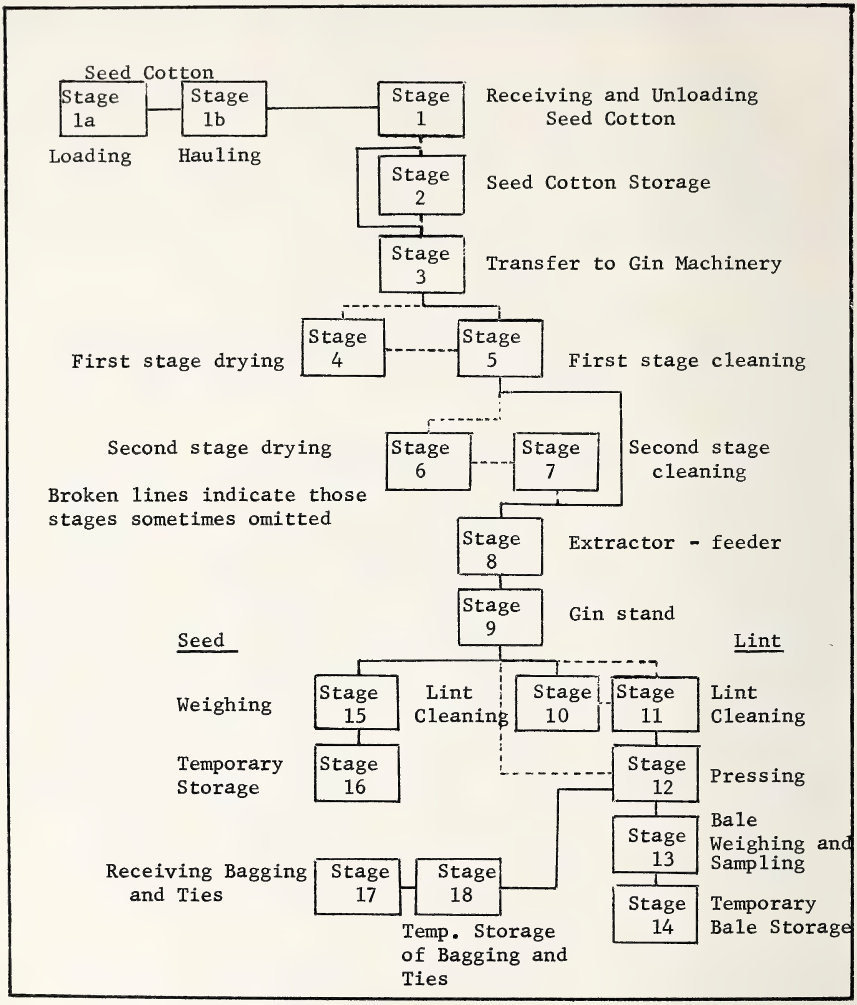

FIGURE 12.—Flow Diagram for a Typical Cotton Gin in Louisiana, 1962. (Source: Adapted from: W. Glenn Tussey and Richard A. King, *Costs of Ginning Cotton in North Carolina,* **North Carolina State College, Department of Agricultural Economics, A. E. Information Series No. 72, November 1959, p. 13.)**

various stages in the plant. This is particularly true in those stages or entire processes which involve batch-type production. In cotton gins, the ginning process is a continuous operation in which the commodity continues to move during the entire process. The automatic feed control regulates the inflow of seed cotton into the process so that a uniform, continuous cotton bat is in process at all times. One exception to this is, of course, when the gin must be cleared between the cotton of two different customers. However, to accomplish this it is not necessary to clear the entire gin, but only enough so that the ginner can distinguish between the customers' cotton and turn the press to start a new bale. In this continuous type of process there is no storage between stages once the commodity has entered the process. Production may be smoothed out by temporary storage of seed cotton prior to ginning. In addition, cottonseed and lint cotton are usually stored at the gin for short periods following ginning.

The Rate Dimension in Cotton Gins

The technical requirements of cotton gins severely limit the variation of ginning rates, or as used herein, the rate dimension. Cotton gins are designed to operate at an optimum speed, and unless cotton is processed at this rate, fiber quality damage results and the customer is penalized. While this relatively fixed rate of flow is overcome in many processing plants by organizing plants in multiple units, this approach in cotton gins, i.e., double battery gins, has been used only to a limited extent in Louisiana. Thompson reports significant dis-economies associated with double battery gins in Texas.[26] With variations in the rate dimension relatively limited, the gin output can be varied to any appreciable degree only by extending the hours of plant operation within any demand period.

The constant rate dimension which is characteristic of cotton gins removes them, at least theoretically, from among those firms with the conventional U-shaped average cost curves of economic theory. When, by necessity, the rate of plant output is held constant and total output varied by varying the number of hours operated per day or week, the uniform level of intensification in the rate sense can be expected to produce relatively constant marginal costs. The linear total cost functions obtained by Paulson in Texas probably resulted from just such variation in the time dimensions.[27] Such being the case with cotton gins, there is reason that average variable costs do not change appreciably as output changes, and consequently marginal costs and average variable costs are for all practical purposes synonymous.[28] Variations in total volume and total cost will result almost entirely from variations in hours of operation per season. Because variable cost and volume are both linear functions of hours, they are also linear functions of each other.[29]

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[26] Russell G. Thompson, "An Economic Analysis of the Revenues Received and the Costs Incurred by Gin Plants in the Plains and Gulf Coast Areas of Texas," unpublished manuscript, Department of Agricultural Economics and Sociology, Texas Agricultural Experiment Station, p. 42.

[27] W. E. Paulson, *Cost and Profit of Ginning Cotton in Texas,* Texas Agricultural Experiment Station, Bulletin No. 606, January 1942, pp. 13-17.

[28] Kenneth E. Boulding, *Economic Analysis* (New York: Harper and Bros., 1948), p. 535.

[29] French, Sammet, and Bressler, *op. cit.,* p. 549.

Given that the average variable cost curve and the marginal cost curve are practically synonymous for cotton gins, the shape of the average total cost curve will be influenced primarily by average fixed costs.

Long-Run Average Costs

The familiar "envelope" long-run average cost curve is usually used to demonstrate the relation between scale and cost. This is represented as points or plants which give least cost over any output interval or output point. As the number of firms increases, the cost-scale relation approaches a smooth curve. In conventional economic theory the declining portion of the long-run average cost curve is made up of points or segments which lie to the left of the least average cost rate of output for each plant (see Figure 13).

However, for certain types of plants, where the opportunity to vary the rate dimension in the production process is limited, as in cotton gins, French and Gillette point out that the conventional long-run average cost curve illustrated in Figure 13 is not applicable.[30] For this type of plant the average cost curves for individual plants decline until a capacity output is reached and then become discontinuous.[31] In this case, higher initial fixed costs, decreasing average fixed cost, and relatively constant

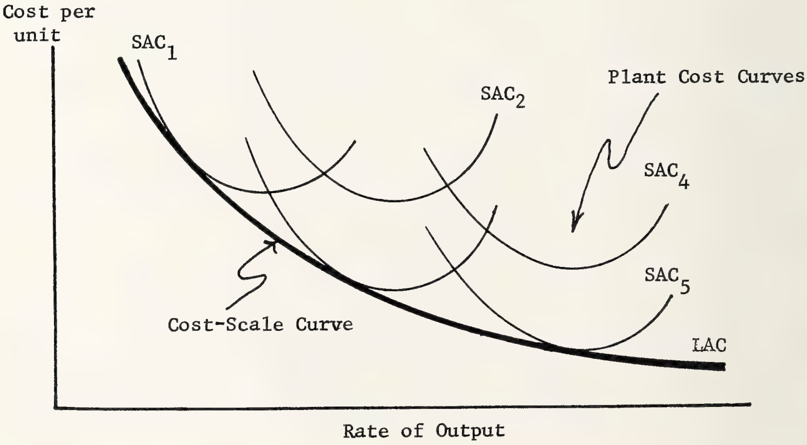

FIGURE 13.—Theoretical Relationship Between Short-Run Average Cost Curves of the Firm and the Long-Run Average Cost Curve.

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[30] B. C. French and D. G. Gillette, *Cost of Assembling and Packing Apples as Related to Scale of Operation*, Michigan Agricultural Experiment Station, Technical Bulletin 272, August 1959, pp. 8-9.

[31] Nowhere in the review of previous cotton gin studies was there any indication that the average total cost curve of gin firms increased within the volume range ordinarily associated with cotton gins.

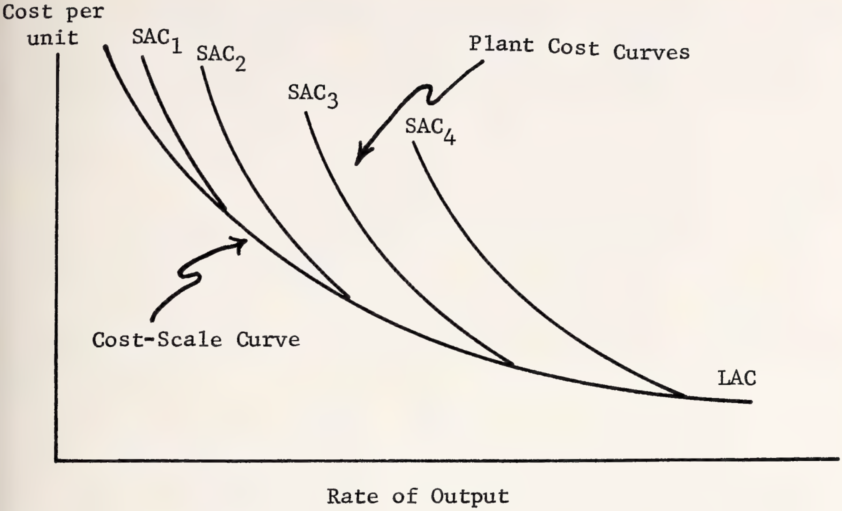

FIGURE 14.—Theoretical Relationship Between Short-Run Average Cost Curves and the Long-Run Average Cost Curve for Cotton Gins.

average variable costs tend to be associated with increased scale. As a result, the "envelope" curve will pass through those points represented by least average cost and capacity of output for each plant (see Figure 14).

Depending on the type of production process involved, plant capacity, as illustrated in Figure 14, is the total quantity of product produced in a given time interval by a plant operating at its most efficient rate of output. This may be a continuous or a discontinuous process. Scale becomes synonymous with size of plant as measured by output if the process is continuous. If the process is discontinuous, as in a processing plant operating only during the harvesting season, a given output can be attained by numerous combinations of rates of output and hours of operation. Generally, however, the range of alternatives is narrowly limited by harvesting periods, market requirements, institutional factors, and such. Because costs associated with producing a given volume of output will vary, cost comparisons between plants of different capacities will be useful only if identical conditions are imposed on all plants.[32]

THE ECONOMIC-ENGINEERING APPROACH

Two approaches can be used to generate data necessary in estimating economies of scale in the ginning industry. One approach is based on a sampling of existing gin plants by the survey technique and the determination of average, annual cost-volume data. This approach, which uses regression techniques, is sometimes referred to as the "statistical" method. A second approach, commonly referred to as the "synthetic" or "economic-engineering" method, involves the construction of hypothetical gin plants from engineering data obtained from gin equipment manufacturers and gin engineers, and deriving investment and operating costs from these data. Usually cost data generated by the economic-engineering method are compared with actual costs to see if they appear to represent "reasonably efficient" operations.[33]

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[32] French and Gillette, *op. cit.*, p. 7.

The disadvantage of the survey method is that it tends to conceal the effects of less than capacity operation and differences in prices on the single cost per unit figure quoted by the plant manager.[34] In attempting to estimate economies of scale by obtaining cost estimates over a range of gin sizes, costs tend to be biased upward. The use of regression techniques to obtain a statistical planning curve is not consistent with the theoretical planning curve since it is an average curve rather than the least cost for producing each volume. Consequently, the statistical planning curve lies above the true planning curve.[35] Knudtson demonstrates this with data from a cost study of four butter plants in Minnesota.[36]

The economic-engineering approach is generally regarded as giving a more accurate picture of the costs faced by a new plant.[37]

Since this study was primarily concerned with developing an analytical framework within which ginners could determine the optimum location and size of cotton gins, the economic-engineering approach to gin costs gave promise of more reliable information. As orginally conceived, an economic-engineering approach was planned. However, limited resources and certain institutional factors prohibited the use of a strict economic-engineering approach. As an alternative to a straight economic-engineering approach, a detailed cost study was made of four completely new, all-electric cotton gins erected in the state during 1961 and 1962.

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[33] French, Sammet, and Bressler, *op. cit.*, p. 585.

[34] Leigh H. Hammond and Richard A. King, *Planning Data for the Sweet Potato Industry, Costs and Returns for a Model Canning Plant,* North Carolina State College, Department of Agricultural Economics, A. E. Information Series No. 93, June 1962, p. 6.

[35] An exception to this would be a regression on only the low points of a scatter diagram as suggested by R. G. Bressler, Jr., "Research Determination of Economics of Scale," *Journal of Farm Economics*, XXVII, (1945), p. 529.

[36] Arvid C. Knudtson, "Estimating Economies of Scale," *Journal of Farm Economics,* XL, (1958), p. 754.

[37] French, Sammet, and Bressler, *op. cit.,* p. 708.

AVERAGE ASSEMBLY COST FUNCTION

With the assumption of uniform production density, the supply of cotton within a circular area surrounding a cotton gin is given by the expression:

(1) $V = DA = D\pi R^2$, where:
$V =$ total volume of cotton available
$D =$ density of production per square miles in bales
$A =$ area in square miles
$R =$ radius or distance from gin in miles.

From equation (1), the supply of cotton within any given distance range will be:[38]

(2) $V_i = V_j - V_k = D\pi R_j^2 - D\pi R_k^2 = D\pi(R_j^2 - R_k^2)\ j > k$
where: V_i is the volume within any distance range
V_j is the volume from zero to distance R_j (upper limit)
V_k is the volume from zero to distance R_k (lower limit).

For any defined interval of travel distance the average assembly cost per bale (AC_a) is a weighted average of the costs for the various distances hauled. This expression is:

$$(3)\quad AC_a = \frac{\sum\limits_{i=1}^{n} AC_{ai} V_i}{\sum\limits_{i=1}^{n} V_i}$$

where: AC_{ai} is the average cost per bale of hauling from the i'th distance

V_i is the bales transported from that distance.

By substituting from equation (2), equation (3) becomes:

$$(4)\quad AC_a = \frac{\sum\limits_{i=1}^{n} AC_{ai} D\pi(R_j^2 - R_k^2)}{\sum\limits_{i=1}^{n} D\pi(R_j^2 - R_k^2)}$$

The average per bale cost of assembly (AC_a) for the i'th distance is expressed by the equation:

(5) $AC_{ai} = L + CR_i$ where:
$L =$ fixed labor costs per bale
$C =$ variable costs per bale mile
$R =$ the i'th distance from the gin.

Earlier it was shown that fixed labor costs were 46.6¢ per bale and variable costs per bale mile were 24.2¢.

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[38] French and Gillette, *op. cit.*, p. 37.

APPENDIX B

APPENDIX TABLE 1.—Fixed Ginning Costs for a Four-Bale-Per-Hour Model Gin Operated for Specified Hours Annually, Area I, Louisiana, 1961-62

Item of cost	Annual hours of operation					
	600	800	1,000	1,200	1,400	1,700
	Dollars					
Fixed costs:						
Management[a]	4,125.00	4,125.00	4,125.00	4,125.00	4,125.00	4,125.00
Office salaries	—	—	—	—	—	—
Depreciation	8,406.67	8,406.67	8,406.67	8,406.67	8,406.67	8,406.67
Interest on investment	4,143.00	4,143.00	4,143.00	4,143.00	4,143.00	4,143.00
Insurance	1,821.88	1,821.88	1,821.88	1,821.88	1,821.88	1,821.88
Taxes	690.50	690.50	690.50	690.50	690.50	690.50
Total fixed costs	19,187.05	19,187.05	19,187.05	19,187.05	19,187.05	19,187.05
Number of bales ginned	2,040	2,720	3,400	4,080	4,760	5,780
Fixed costs per bale (dollars)	9.41	7.05	5.64	4.70	4.03	3.32

[a] Includes employer's contribution to Social Security.

APPENDIX TABLE 2.—Fixed Ginning Costs for a Four-Bale-per-Hour Model Gin Operated for Specified Hours Annually, Area II, Louisiana, 1961-62

Item of cost	Annual hours of operation					
	600	800	1,000	1,200	1,400	1,700
	Dollars					
Fixed costs:						
Management[a]	4,125.00	4,125.00	4,125.00	4,125.00	4,125.00	4,125.00
Office salaries	—	—	—	—	—	—
Depreciation	13,880.00	13,880.00	13,880.00	13,880.00	13,880.00	13,880.00
Interest on investment	4,143.00	4,143.00	4,143.00	4,143.00	4,143.00	4,143.00
Insurance	1,821.88	1,821.88	1,821.88	1,821.88	1,821.88	1,821.88
Taxes	690.50	690.50	690.50	690.50	690.50	690.50
Total fixed costs	24,660.38	24,660.38	24,660.38	24,660.38	24,660.38	24,660.38
Number of bales ginned	2,040	2,720	3,400	4,080	4,760	5,780
Fixed costs per bale (dollars)	12.09	9.07	7.25	6.04	5.18	4.27

[a] Includes employer's contribution to Social Security.

APPENDIX TABLE 3.—Variable Ginning Costs for a Four-Bale-per-Hour Model Gin Operated for Specified Hours Annually, Areas I and II, Louisiana, 1961-62

Item of cost	Annual hours of operation					
	600	800	1,000	1,200	1,400	1,700
			Dollars			
Variable costs:						
Bagging and ties	5,100.00	6,800.00	8,500.00	10,200.00	11,900.00	14,450.00
Labor[a] ($1.00 per hr.)	1,856.25	2,475.00	3,093.75	3,712.50	4,331.25	5,259.38
($1.25 per hr.)	2,320.31	3,093.75	3,867.19	4,640.62	5,414.06	6,574.22
Repairs	1,713.60	2,094.40	2,380.00	2,733.60	3,094.00	3,699.20
Power	4,129.98	5,238.51	6,347.05	7,455.59	8,564.12	10,226.91
Drier fuel	235.07	295.33	353.78	414.44	473.99	563.31
Yard insurance	34.69	46.37	57.17	69.47	81.10	98.41
Compensation & liability insurance						
($1.00 per hr.)	149.22	198.96	248.70	298.44	348.18	422.79
($1.25 per hr.)	186.52	248.70	310.88	373.05	435.22	528.49
Gin supplies	408.00	516.80	612.00	693.60	761.60	867.00
Travel expenses	204.00	244.80	272.00	326.40	333.20	404.60
Office supplies	244.80	299.20	340.00	408.00	428.40	520.20
Telephone and telegraph	163.20	217.60	238.00	285.60	285.60	346.80
Legal and audit	122.40	163.20	170.00	183.60	190.40	231.20
Miscellaneous	204.00	272.00	340.00	408.00	476.00	578.00
Total variable costs						
($1.00 per hr.)	14,565.21	18,862.17	22,952.45	27,189.24	31,267.84	37,667.80
($1.25 per hr.)	15,066.57	19,530.66	23,788.07	28,191.97	32,437.69	39,088.34
Variable costs per bale						
($1.00 per hr.)	7.14	6.93	6.75	6.60	6.57	6.52
($1.25 per hr.)	7.39	7.18	7.00	6.91	6.81	6.76

[a] Includes employer's contribution to Social Security.

Louisiana, 1961-62

Item of cost	Annual hours of operation					
	600	800	1,000	1,200	1,400	1,700
	Dollars					
Fixed costs:						
Management[a]	5,156.25	5,156.25	5,156.25	5,156.25	5,156.26	5,156.25
Office salaries[a]	1,031.25	1,031.25	1,031.25	1,031.25	1,031.25	1,031.25
Depreciation	13,296.67	13.296.67	13,296.67	13,296.67	13,396.67	13,296.67
Interest on investment	6,567.00	6,567.00	6,567.00	6,567.00	6,567.00	6,567.00
Insurance	2,886.68	2,886.68	8,886.68	2,886.68	2,886.68	2,886.68
Taxes	1,094.50	1,094.50	1,094.50	1,094.50	1,094.50	1,094.50
Total fixed costs	30,032.35	30,032.35	30,032.35	30,032.35	30,032.35	30,032.35
Number of bales ginned	4,080	5,440	6,800	8,160	9,520	11,560
Fixed costs per bale (dollars)	7.36	5.52	4.42	3.68	3.15	2.60

[a] Includes employer's contribution to Social Security.

APPENDIX TABLE 5.—Fixed Ginning Costs for an Eight-Bale-per-Hour Model Gin Operated for Specified Hours Annually, Area II, Louisiana, 1961-62

Item of cost	Annual hours of operation					
	600	800	1,000	1,200	1,400	1,700
	Dollars					
Fixed costs:						
Management[a]	5,156.25	5,156.25	5,156.25	5,156.25	5,156.25	5,156.25
Office salaries[a]	1,031.25	1,031.25	1,031.25	1,031.25	1,031.25	1,031.25
Depreciation	21,960.00	21,960.00	21,960.00	21,960.00	21,960.00	21,960.00
Interest on investment	6,567.00	6,567.00	6,567.00	6,567.00	6,567.00	6,567.00
Insurance	2,886.68	2,886.68	2,886.68	2,886.68	2,886.68	2,886.68
Taxes	1,094.50	1,094.50	1,094.50	1,094.50	1,094.50	1,094.50
Total fixed costs	38,695.68	38,695.68	38,695.68	38,695.68	38,695.68	38,695.68
Number of bales ginned	4,080	5,440	6,800	8,160	9,520	11,560
Fixed costs per bale (dollars)	9.48	7.11	5.69	4.74	4.06	3.35

[a] Includes employer's contribution to Social Security.

APPENDIX TABLE 6.—Variable Ginning Costs for an Eight-Bale-per-Hour Model Gin Operated for Specified Hours Annually, Areas I and II, Louisiana, 1961-62

Item of cost		Annual hours of operation					
		600	800	1,000	1,200	1,400	1,700
				Dollars			
Variable costs:							
Bagging and ties		10,200.00	13,600.00	17,000.00	20,400.00	23,800.00	28,900.00
Labor[a]	($1.00 per hr.)	3,712.50	4,950.00	6,187.50	7,425.00	8,662.50	10,518.75
	($1.25 per hr.)	4,640.63	6,187.50	7,734.38	9,281.25	10,828.13	13,148.44
Repairs		2,733.60	3,427.20	4,080.00	4,814.40	5,569.20	6,704.80
Power		6,972.80	8,874.23	10,775.63	12,677.03	14,578.46	17,430.56
Drier fuel		298.01	378.36	458.74	539.08	619.41	739.92
Yard insurance		69.53	92.57	115.72	139.00	162.14	196.78
Compensation & liability insurance							
	($1.00 per hr.)	298.44	397.92	497.40	596.88	696.36	845.58
	($1.25 per hr.)	373.05	497.40	621.75	746.10	870.45	1,056.98
Gin supplies		816.00	1,033.60	1,224.00	1,387.20	1,523.70	1,734.00
Travel expenses		408.00	489.60	544.00	652.80	666.40	809.20
Office supplies		489.60	598.40	680.00	816.00	856.80	1,040.40
Telephone and telegraph		326.40	408.00	476.00	530.40	571.20	693.60
Legal and audit		244.80	299.20	340.00	367.20	380.80	462.40
Miscellaneous		408.00	544.00	680.00	816.00	952.00	1,156.00
Total variable costs							
	($1.00 per hr.)	26,977.68	35,093.08	43,058.99	51,160.99	59,038.95	71,231.99
	($1.25 per hr.)	27,980.42	36,430.06	44,730.22	53,166.46	61,378.67	74,073.08
Variable costs per bale							
	($1.00 per hr.)	6.61	6.45	6.33	6.27	6.20	6.16
	($1.25 per hr.)	6.86	6.70	6.58	6.52	6.45	6.41

[a] Includes employer's contribution to Social Security.

Louisiana, 1961-62

Item of cost	600	800	1,000	1,200	1,400	1,700
	Annual hours of operation					
	Dollars					
Fixed costs:						
Management[a]	6,187.50	6,187.50	6,187.50	6,187.50	6,187.50	6,187.50
Office salaries[a]	1,546.88	1,546.88	1,546.88	1,546.88	1,546.88	1,546.88
Depreciation	16,926.67	16,926.67	16,926.67	16,926.67	16,926.67	16,926.67
Interest on investment	8,376.00	8,376.00	8,376.00	8,376.00	8,376.00	8,376.00
Insurance	3,682.30	3,682.30	3,682.30	3,682.30	3,682.30	3,682.30
Taxes	1,396.00	1,396.00	1,396.00	1,396.00	1,396.00	1,396.00
Total fixed costs	38,115.35	38,115.35	38,115.35	38,115.35	38,115.35	38,115.35
Number of bales ginned	6,120	8,160	10,200	12,240	14,280	17,340
Fixed costs per bale (dollars)	6.23	4.67	3.74	3.11	2.67	2.20

[a] Includes employer's contribution to Social Security.

APPENDIX TABLE 8.—Fixed Ginning Costs for a Twelve-Bale-per-Hour Model Gin Operated for Specified Hours Annually, Area II, Louisiana, 1961-62

Item of cost	600	800	1,000	1,200	1,400	1,700
	Annual hours of operation					
	Dollars					
Fixed costs:						
Management[a]	6,187.50	6,187.50	6,187.50	6,187.50	6,187.50	6,187.50
Office salaries[a]	1,546.88	1,546.88	1,546.88	1,546.88	1,546.88	1,546.88
Depreciation	27,990.00	27,990.00	27,990.00	27,990.00	27,990.00	27,990.00
Interest on investment	8,376.00	8,376.00	8,376.00	8,376.00	8,376.00	8,376.00
Insurance	3,682.30	3,682.30	3,682.30	3,682.30	3,682.30	3,682.30
Taxes	1,396.00	1,396.00	1,396.00	1,396.00	1,396.00	1,396.00
Total fixed costs	49,178.68	49,178.68	49,178.68	49,178.68	49,178.68	49,178.68
Number of bales ginned	6,120	8,160	10,200	12,240	14,280	17,340
Fixed costs per bale (dollars)	8.04	6.03	4.82	4.02	3.44	2.84

[a] Includes employer's contribution to Social Security.

APPENDIX TABLE 9.—Variable Ginning Costs for a Twelve-Bale-per-Hour Model Gin Operated for Specified Hours Annually, Areas I and II, Louisiana, 1961-62

Item of cost	Annual hours of operation					
	600	800	1,000	1,200	1,400	1,700
			Dollars			
Variable costs:						
Bagging and ties	15,300.00	20,400.00	25,500.00	30,600.00	35,700.00	43,350.00
Labor[a] ($1.00 per hr.)	4,331.25	5,775.00	7,218.75	8,662.50	10,106.25	12,271.88
($1.25 per hr.)	5,414.06	7,218.75	9,023.44	10,828.13	12,632.81	15,339.84
Repairs	3,672.00	4,651.20	5,610.00	6,609.60	7,711.20	9,363.60
Power	9,387.81	12,023.49	14,659.17	17,294.85	19,930.53	23,884.05
Drier fuel	376.91	454.20	553.48	652.80	752.10	900.51
Yard insurance	104.25	138.99	173.69	208.40	243.17	295.22
Compensation & liability insurance						
($1.00 per hr.)	348.18	464.24	580.30	696.36	812.42	986.51
($1.25 per hr.)	435.22	580.30	725.38	870.45	1,015.52	1,233.14
Gin supplies	1,101.60	1,387.20	1,632.00	1,836.00	1,999.20	2,254.20
Travel expenses	550.80	652.80	714.00	795.60	856.80	1,040.40
Office supplies	612.00	734.40	816.00	918.00	999.60	1,213.80
Telephone and telegraph	428.40	530.40	612.00	673.20	714.00	867.00
Legal and audit	367.20	448.80	510.00	550.80	571.20	693.60
Miscellaneous	612.00	816.00	1,200.00	1,224.00	1,428.00	1,734.00
Total variable costs						
($1.00 per hr.)	37,192.40	48,476.72	59,779.39	70,722.11	81,824.47	98,854.77
($1.25 per hr.)	38,362.25	50,036.53	61,729.16	73,061.83	84,554.13	102,169.36
Variable costs per bale						
($1.00 per hr.)	6.08	5.94	5.86	5.78	5.73	5.70
($1.25 per hr.)	6.27	6.13	6.05	5.97	5.92	5.89

[a] Includes employer's contribution to Social Security.

APPENDIX TABLE 10.—Fixed Ginning Costs for a Fifteen-Bale-per-Hour Model Gin Operated for Specified Hours Annually, Area I, Louisiana, 1961-62

Item of cost	Annual hours of operation					
	600	800	1,000	1,200	1,400	1,700
	Dollars					
Fixed costs:						
Management[a]	7,218.75	7,218.75	7,218.75	7,218.75	7,218.75	7,218.75
Office salaries[a]	1,546.88	1,546.88	1,546.88	1,546.88	1,546.88	1,546.88
Depreciation	20,413.33	20,413.33	20,413.33	20,413.33	20,413.33	20,413.33
Interest on investment	9,999.00	9,999.00	9,999.00	9,999.00	9,999.00	9,999.00
Insurance	4,394.49	4,394.49	4,394.49	4,394.49	4,394.49	4,394.49
Taxes	1,666.00	1,666.00	1,666.00	1,666.00	1,666.00	1,666.00
Total fixed costs	45,238.45	45,238.45	45,238.45	45,238.45	45,238.45	45,238.45
Number of bales ginned	7,650	10,200	12,750	15,300	17,850	21,675
Fixed costs per bale (dollars)	5.91	4.44	3.55	2.96	2.53	2.09

[a] Includes employer's contribution to Social Security.

APPENDIX TABLE 11.—Fixed Ginning Costs for a Fifteen-Bale-per-Hour Model Gin Operated for Specified Hours Annually, Area II, Louisiana, 1961-62

Item of cost	Annual hours of operation					
	600	800	1,000	1,200	1,400	1,700
	Dollars					
Fixed costs:						
Management[a]	7,218.75	7,218.75	7,218.75	7,218.75	7,218.75	7,218.75
Office salaries[a]	1,546.88	1,546.88	1,546.88	1,546.88	1,546.88	1,546.88
Depreciation	33,400.00	33,400.00	33,400.00	33,400.00	33,400.00	33,400.00
Interest on investment	9,999.00	9,999.00	9,999.00	9,999.00	9,999.00	9,999.00
Insurance	4,394.49	4,394.49	4,394.49	4,394.49	4,394.49	4,394.49
Taxes	1,666.00	1,666.00	1,666.00	1,666.00	1,666.00	1,666.00
Total fixed costs	58,225.12	58,225.12	58,225.12	58,225.12	58,225.12	58,225.12
Number of bales ginned	7,650	10,200	12,750	15,300	17,850	21,675
Fixed costs per bale (dollars)	7.61	5.71	4.57	3.81	3.26	2.69

[a] Includes employer's contribution to Social Security.

APPENDIX TABLE 12.—Variable Ginning Costs for a Fifteen-Bale-per-Hour Model Gin Operated for Specified Hours Annually, Areas I and II, Louisiana, 1961-62

Item of cost	Annual hours of operation					
	600	800	1,000	1,200	1,400	1,700
			Dollars			
Variable costs:						
Bagging and ties	19,125.00	25,500.00	31,875.00	38,250.00	44,625.00	54,187.50
Labor[a] ($1.00 per hr.)	4,950.00	6,600.00	8,250.00	9,900.00	11,550.00	14,025.00
($1.25 per hr.)	6,187.50	8,250.00	10,312.50	12,375.00	14,437.50	17,531.25
Repairs	4,284.00	5,406.00	6,693.75	7,956.00	9,282.00	11,271.00
Power	11,021.05	14,160.61	17,300.17	20,439.73	23,579.29	28,288.65
Drier fuel	412.45	530.93	647.23	767.90	895.90	1,062.87
Yard insurance	130.22	173.75	217.10	260.48	303.89	369.05
Compensation & liability insurance						
($1.00 per hr.)	397.92	530.56	663.20	795.84	928.48	1,127.44
($1.25 per hr.)	497.40	663.20	829.00	994.80	1,160.60	1,409.30
Gin supplies	1,377.00	1,734.00	2,040.00	2,295.00	2,499.00	2,817.75
Travel expenses	612.00	714.00	765.00	841.50	892.50	1,083.75
Office supplies	688.50	816.00	892.50	994.50	1,071.00	1,300.50
Telephone and telegraph	459.00	561.00	673.50	688.50	714.00	867.00
Legal and audit	497.25	612.00	701.25	765.00	803.25	975.37
Miscellaneous	765.00	1,020.00	1,275.00	1,530.00	1,785.00	2,167.50
Total variable costs						
($1.00 per hr.)	44,719.39	58,358.85	71,993.70	85,484.45	98,929.31	119,543.38
($1.25 per hr.)	46,056.37	60,141.49	74,222.00	88,158.41	102,048.93	123,331.49
Variable costs per bale						
($1.00 per hr.)	5.85	5.72	5.64	5.59	5.54	5.52
($1.25 per hr.)	6.02	5.90	5.82	5.76	5.72	5.69

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[a] Includes employer's contribution to Social Security.

APPENDIX TABLE 13.—Combined per Bale Costs of Assembly and Ginning, Four-Bale-per-Hour Model Gins, Four Levels of Production Density, Two Hourly Wage Rates, Areas I and II, Louisiana, 1961-62

Annual volume	Area I		Area II	
	Hourly wage rate		Hourly wage rate	
	$1.00	$1.25	$1.00	$1.25
Bales	*Dollars*	*Dollars*	*Dollars*	*Dollars*
	50 Bales per Square Mile			
2,000	17.90	18.10	20.60	21.00
3,000	14.67	15.02	16.57	16.82
4,000	13.00	13.30	14.35	14.65
5,000	12.16	12.36	13.26	13.46
6,000	11.65	11.95	12.55	11.80
	100 Bales per Square Mile			
2,000	17.69	17.89	20.39	20.79
3,000	14.39	14.74	16.29	16.54
4,000	12.67	12.97	14.02	14.32
5,000	11.78	11.98	12.88	13.08
6,000	11.23	11.53	12.13	12.38
	200 Bales per Square Mile			
2,000	17.53	17.73	20.23	20.63
3,000	14.19	14.54	16.09	16.34
4,000	12.44	12.74	13.79	14.09
5,000	11.51	11.71	12.61	12.81
6,000	10.93	11.23	11.83	12.08
	300 Bales per Square Mile			
2,000	17.47	17.67	20.17	20.57
3,000	14.11	14.46	16.01	16.26
4,000	12.33	12.63	13.68	13.98
5,000	11.39	11.59	12.49	12.69
6,000	10.80	11.10	11.70	11.95

APPENDIX TABLE 14.—Combined per Bale Costs of Assembly and Ginning, Eight-Bale-per-Hour Model Gins, Four Levels of Production Density, Two Hourly Wage Rates, Areas I and II, Louisiana, 1961-62

Annual volume	Area I		Area II	
	Hourly wage rate		Hourly wage rate	
	$1.00	$1.25	$1.00	$1.25
Bales	*Dollars*	*Dollars*	*Dollars*	*Dollars*
	50 Bales per Square Mile			
4,000	15.70	15.90	17.80	18.05
5,000	14.21	14.51	15.91	16.26
6,000	13.30	13.55	14.75	15.05
7,000	12.62	12.92	13.92	14.12
8,000	12.14	12.44	13.24	13.49
9,000	11.79	12.04	12.79	12.99
10,000	11.54	11.74	12.44	12.64
11,000	11.34	11.54	12.09	12.34
12,000	11.19	11.44	11.94	12.19
	100 Bales per Square Mile			
4,000	15.37	15.57	17.47	17.72
5,000	13.83	14.13	15.53	15.88
6,000	12.88	13.13	14.33	14.63
7,000	12.16	12.46	13.46	13.66
8,000	11.65	11.95	12.75	13.00
9,000	11.27	11.52	12.27	12.47
10,000	11.00	11.20	11.90	12.10
11,000	10.76	10.96	11.51	11.76
12,000	10.58	10.83	11.33	11.58
	200 Bales per Square Mile			
4,000	15.14	15.34	17.24	17.49
5,000	13.56	13.86	15.26	15.61
6,000	12.58	12.83	14.03	14.33
7,000	11.84	12.14	13.14	13.34
8,000	11.30	11.60	12.40	12.65
9,000	10.90	11.15	11.90	12.10
10,000	10.60	10.80	11.50	11.70
11,000	10.35	10.55	11.10	11.35
12,000	10.15	10.40	10.90	11.15
	300 Bales per Square Mile			
4,000	15.03	15.23	17.13	17.38
5,000	13.44	13.74	15.14	15.49
6,000	12.45	12.70	13.90	14.20
7,000	11.70	12.00	13.00	13.20
8,000	11.15	11.45	12.25	12.50
9,000	10.74	10.99	11.74	11.94
10,000	10.43	10.63	11.33	11.53
11,000	10.17	10.37	10.92	11.17
12,000	9.96	10.21	10.71	10.96

APPENDIX TABLE 15.—Combined per Bale Costs of Assembly and Ginning, Twelve-Bale-per-Hour Model Gins, Four Levels of Production Density, Two Hourly Wage Rates, Areas I and II, Louisiana, 1961-62

Annual volume	Area I		Area II	
	Hourly wage rate		Hourly wage rate	
	$1.00	$1.25	$1.00	$1.25
Bales	*Dollars*	*Dollars*	*Dollars*	*Dollars*
50 Bales per Square Mile				
6,000	14.35	14.55	16.20	16.50
7,000	13.47	13.62	15.02	15.22
8,000	12.84	13.04	14.24	14.39
9,000	12.44	12.59	13.64	13.84
10,000	12.04	12.19	13.13	13.24
11,000	11.74	11.89	12.74	12.89
12,000	11.54	11.69	12.44	12.59
13,000	11.32	11.47	12.17	12.32
14,000	11.16	11.31	11.96	12.11
15,000	11.04	11.19	11.79	11.94
16,000	10.97	11.12	11.62	11.77
17,000	10.89	11.04	11.54	11.69
18,000	10.82	11.02	11.37	11.62
100 Bales per Square Mile				
6,000	13.93	14.13	15.78	16.08
7,000	13.01	13.60	14.56	14.76
8,000	12.35	12.55	13.75	13.90
9,000	11.92	12.07	13.12	13.32
10,000	11.50	11.65	12.60	12.70
11,000	11.16	11.31	12.16	12.31
12,000	10.93	11.08	11.83	11.98
13,000	10.69	10.84	11.54	11.69
14,000	10.50	10.65	11.30	11.45
15,000	10.36	10.51	11.11	11.26
16,000	10.26	10.41	10.91	11.06
17,000	10.17	10.32	10.82	10.97
18,000	10.07	10.27	10.62	10.87
200 Bales per Square Mile				
6,000	13.63	13.83	15.48	15.78
7,000	12.69	12.84	14.24	14.44
8,000	12.00	12.20	13.40	13.55
9,000	11.55	11.70	12.75	12.95
10,000	11.10	11.25	12.20	12.30
11,000	10.75	10.90	11.75	11.90
12,000	10.50	10.65	11.40	11.55
13,000	10.24	10.39	11.09	11.24
14,000	10.04	10.19	10.84	10.99
15,000	9.88	10.03	10.63	10.78
16,000	9.77	9.92	10.42	10.57
17,000	9.65	9.80	10.30	10.45
18,000	9.54	9.74	10.09	10.34

(Continued)

APPENDIX TABLE 15.—(Continued)

Annual volume	Area I		Area II	
	Hourly wage rate		Hourly wage rate	
	$1.00	$1.25	$1.00	$1.25
Bales	*Dollars*	*Dollars*	*Dollars*	*Dollars*
	300 Bales per Square Mile			
6,000	13.50	13.70	15.35	15.65
7,000	12.55	12.70	14.10	14.30
8,000	11.85	12.05	13.25	13.40
9,000	11.39	11.54	12.59	12.79
10,000	10.93	11.08	12.03	12.13
11,000	10.57	10.72	11.57	11.72
12,000	10.31	10.46	11.21	11.36
13,000	10.05	10.20	10.90	11.05
14,000	9.83	9.98	10.63	10.78
15,000	9.67	9.82	10.42	10.57
16,000	9.55	9.70	10.20	10.35
17,000	9.43	9.58	10.08	10.23
18,000	9.31	9.51	9.86	10.11

APPENDIX TABLE 16.—Combined per Bale Costs of Assembly and Ginning, Fifteen-Bale-per-Hour Model Gins, Four Levels of Production Density, Two Hourly Wage Rates, Areas I and II, Louisiana, 1961-62

Annual volume	Area I		Area II	
	Hourly wage rate		Hourly wage rate	
	$1.00	$1.25	$1.00	$1.25
Bales	*Dollars*	*Dollars*	*Dollars*	*Dollars*
	50 Bales per Square Mile			
7,000	14.37	14.62	16.27	16.47
8,000	13.64	13.84	15.24	15.44
9,000	13.04	13.24	14.49	14.64
10,000	12.59	12.79	13.94	14.09
11,000	12.24	12.44	13.49	13.64
12,000	11.99	12.19	13.14	13.24
13,000	11.72	11.92	12.77	12.92
14,000	11.56	11.76	12.51	12.66
15,000	11.39	11.59	12.29	12.44
16,000	11.27	11.47	12.07	12.27
17,000	11.14	11.34	11.94	12.09
18,000	11.07	11.27	11.82	11.97
19,000	10.99	11.19	11.69	11.84
20,000	10.96	11.11	11.61	11.76
21,000	10.93	11.08	11.53	11.68
22,000	10.90	11.05	11.45	11.60

(Continued)

APPENDIX TABLE 16.—(Continued)

Annual volume	Area I		Area II	
	Hourly wage rate		Hourly wage rate	
	$1.00	$1.25	$1.00	$1.25
Bales	*Dollars*	*Dollars*	*Dollars*	*Dollars*
100 Bales per Square Mile				
7,000	13.91	14.16	15.81	16.01
8,000	13.15	13.35	14.75	14.95
9,000	12.52	12.72	13.97	14.12
10,000	12.05	12.25	13.40	13.55
11,000	11.66	11.86	12.91	13.06
12,000	11.38	11.58	12.53	12.63
13,000	11.09	11.29	12.14	12.29
14,000	10.90	11.10	11.85	12.00
15,000	10.71	10.91	11.61	11.76
16,000	10.56	10.76	11.36	11.56
17,000	10.42	10.62	11.22	11.37
18,000	10.32	10.52	11.07	11.22
19,000	10.22	10.42	10.92	11.07
20,000	10.17	10.32	10.82	10.97
21,000	10.12	10.27	10.72	10.87
22,000	10.06	10.21	10.61	10.76
200 Bales per Square Mile				
7,000	13.59	13.84	15.49	15.69
8,000	12.80	13.00	14.40	14.60
9,000	12.15	12.35	13.60	13.75
10,000	11.65	11.90	13.00	13.15
11,000	11.25	11.45	12.50	12.65
12,000	10.95	11.15	12.10	12.20
13,000	10.64	10.80	11.69	11.84
14,000	10.44	10.64	11.39	11.54
15,000	10.23	10.43	11.13	11.28
16,000	10.07	10.27	10.87	11.07
17,000	9.90	10.10	10.70	10.85
18,000	9.79	9.99	10.54	10.69
19,000	9.68	9.88	10.38	10.53
20,000	9.61	9.76	10.26	10.41
21,000	9.55	9.70	10.15	10.30
22,000	9.48	9.63	10.03	10.18
300 Bales per Square Mile				
7,000	13.45	13.70	15.35	15.55
8,000	12.65	12.85	14.25	14.45
9,000	11.99	12.19	13.44	13.59
10,000	11.48	11.68	12.83	12.98
11,000	11.07	11.27	12.32	12.47
12,000	10.76	10.96	11.91	12.01
13,000	10.45	10.65	11.50	11.65
14,000	10.23	10.43	11.18	11.33
15,000	10.02	10.22	10.92	11.07
16,000	9.85	10.05	10.65	10.85
17,000	9.68	9.88	10.48	10.63
18,000	9.56	9.76	10.31	10.46
19,000	9.44	9.64	10.14	10.29
20,000	9.36	9.51	10.01	10.16
21,000	9.29	9.44	9.89	10.04
22,000	9.22	9.37	9.77	9.92

APPENDIX TABLE 17.—Fixed, Variable, and Total Costs of Seed Cotton Storage in Baskets for a Four-Bale-per-Hour Gin Operated for Specified Annual Volumes, Two Wage Rates, Louisiana, 1961-62

Item	Annual volume in bales		
	2,000[a]	6,000	7,000
	Dollars	*Dollars*	*Dollars*
Fixed costs	5,111.71	5,111,71	5,111.71
Variable costs:			
Labor ($1.00 per hour)	—	27.23	350.65
($1.25 per hour)	—	34.03	438.28
Power	—	10.49	134.92
Fuel, oil, grease	—	2.64	34.00
Repairs & maintenance	—	11.88	153.00
Yard insurance	—	1.03	13.03
Compensation & liability insurance			
($1.00 per hour)	—	2.18	28.19
($1.25 per hour)	—	2.74	35.23
Total variable costs			
($1.00 per hour)	—	55.45	713.79
($1.25 per hour)	—	62.81	808.46
Total costs			
($1.00 per hour)	5,111.71	5,167.16	5,825.50
($1.25 per hour)	5,111.71	5,174.52	5,920.17
Cost per bale ginned			
($1.00 per hour)	2.56	.86	.83
($1.25 per hour)	2.56	.86	.85

[a] No storage is utilized until a volume of 6,000 bales is reached. Total costs per bale reflect only fixed costs until this volume is attained, and are as follows: 3,000 - $1.70, 4,000 - $1.28, 5,000 - $1.02.

APPENDIX TABLE 18.—Fixed, Variable, and Total Costs of Seed Cotton Storage in Baskets for an Eight-Bale-per-Hour Gin Operated for Specified Annual Volumes, Two Wage Rates, Louisiana, 1961-62

Item	Annual volume in bales			
	4,000[a]	12,000	13,000	14,000
	Dollars	*Dollars*	*Dollars*	*Dollars*
Fixed costs	9,513.78	9,513.78	9,513.78	9,513.78
Variable costs:				
Labor ($1.00 per hour)	—	54.45	257.81	701.25
($1.25 per hour)	—	68.06	322.27	876.56
Power	—	20.94	99.23	269.86
Fuel, oil, grease	—	5.28	25.00	68.00
Repairs & maintenance	—	146.00	215.00	303.00
Yard insurance	—	2.05	9.73	26.05
Compensation & liability insurance				
($1.00 per hour)	—	4.38	20.72	56.37
($1.25 per hour)	—	5.47	25.91	70.46
Total variable costs				
($1.00 per hour)	—	233.10	627.49	1,424.53
($1.25 per hour)	—	247.80	697.14	1,613.93
Total costs				
($1.00 per hour)	9,513.78	9,746.88	10,141.27	10,938.31
($1.25 per hour)	9,513.78	9,761.58	10,210.92	11,127.71
Costs per bale ginned				
($1.00 per hour)	2.38	.81	.78	.78
($1.25 per hour)	2.38	.81	.79	.79

[a] No storage is utilized until a volume of 12,000 bales is reached. Total costs per bale reflect only fixed costs until this volume is attained, and are as follows: 5,000 - $1.90, 6,000 - $1.59, 7,000 - $1.36, 8,000 - $1.19, 9,000 - $1.06, 10,000 - $0.95, 11,000 - $0.86.

APPENDIX TABLE 19.—Fixed, Variable, and Total Costs of Seed Cotton Storage in Baskets for a Twelve-Bale-per-Hour Gin Operated for Specified Annual Volumes, Two Wage Rates, Louisiana, 1961-62

Item	Annual volume in bales				
	6,000[a]	18,000	19,000	20,000	21,000
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Fixed costs	13,985.02	13,985.02	13,985.02	13,985.02	13,985.02
Variable costs:					
Labor ($1.00 per hour)	—	40.84	130.14	256.58	525.94
($1.25 per hour)	—	51.05	162.68	320.72	657.42
Power	—	31.43	100.17	197.47	404.80
Fuel, oil, grease	—	7.92	25.24	49.76	102.00
Repairs & maintenance	—	205.00	300.00	400.00	420.00
Yard insurance	—	3.08	9.82	19.34	39.12
Compensation & liability insurance					
($1.00 per hour)	—	3.39	10.46	20.63	42.28
($1.25 per hour)	—	4.23	13.08	25.78	52.85
Total variable costs					
($1.00 per hour)	—	291.66	575.83	943.78	1,534.14
($1.25 per hour)	—	302.71	610.99	1,013.07	1,676.19
Total costs					
($1.00 per hour)	13,985.02	14,276.68	14,560.85	14,928.80	15,519.16
($1.25 per hour)	13,985.02	14,287.73	14,596.01	14,998.09	15,661.21
Costs per bale ginned					
($1.00 per hour)	2.33	.79	.77	.75	.74
($1.25 per hour)	2.33	.79	.77	.75	.75

[a] No storage is utilized until a volume of 18,000 bales is reached. Total costs per bale reflect only fixed costs until this volume is attained, and are as follows: 7,000 - $2.00, 8,000 - $1.75, 9,000 - $1.55, 10,000 - $1.40, 11,000 - $1.27, 12,000 - $1.16, 13,000 - $1.08, 14,000 - $1.00, 15,000 - $0.93, 16,000 - $0.87, 17,000 - $0.82.

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BULLETIN NO. 578

A Stochastic Analysis of Size Distribution Of Firms In Fluid Milk Markets *In Louisiana*

A TECHNICAL PRESENTATION BY

D. C. Williams and W. H. Alexander

DEPARTMENT OF AGRICULTURAL ECONOMICS
AND AGRIBUSINESS
Louisiana State University and
Agricultural and Mechanical College
Agricultural Experiment Station
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A Stochastic Analysis of Size Distribution of Firms in Fluid Milk Markets in Louisiana

By

D. C. Williams, Jr.
and
William H. Alexander

Department of Agricultural Economics
and Agribusiness

Louisiana State University
and
Agricultural and Mechanical College

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Charles W. Upp, Director
DECEMBER 1963

FOREWORD

Changes have been taking place in the structure of the Louisiana dairy industry in terms of number and size distribution of firms, growth patterns, and mobility, as well as survival rates for firms. This publication reports the results of a study concerning these changes in both the milk producing industry and the milk processing and distribution segment. The Markov Chain technique was employed in the quantitative analysis.

Specifically, the study includes: (1) a description of structural changes in milk producing, processing, and distributing firms operating in Louisiana markets; (2) estimates of the number and size distribution of such firms in selected future time periods; (3) estimates of the number and size distribution of firms in a theoretical industry equilibrium; and (4) indices of firm mobility (in terms of changes in size) in the markets.

ACKNOWLEDGMENTS

The authors wish to acknowledge the assistance of the Market Administrators of the New Orleans and the Northern Louisiana Federal Milk Marketing Orders, the Division of Milk Testing of the Louisiana Department of Agriculture and Immigration, and the managers of the Milk Producer Cooperatives in Louisiana in providing the basic data essential to the success of this study.

Appreciation is extended to members of the Department, and especially Professor Leo Polopolus and the late Dr. Jack D. Johnson, for helpful suggestions during the study and in the preparation of the manuscript. Recognition is also extended to Professor Max Langham for his suggestions in the early phase of this study.

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A Stochastic Analysis of Size Distribution of Firms in Fluid Milk Markets in Louisiana

D. C. Williams, Jr., and William H. Alexander
Department of Agricultural Economics and Agribusiness

INTRODUCTION

In the dynamic American economy the market structure of most industries is changing toward fewer and larger firms. The emerging distribution of firm size is of particular interest to economists, principally in its structural relation to the phenomena of competition and oligopoly and in the issues of government regulation.[1]

Economic theory suggests that the concentration of firms in a market, as defined by their number and relative size distribution, is an important determinant of market behavior and market results.[2] Where a small number of firms account for the bulk of a market's output, monopolistic practices are more likely, *ceteris paribus,* than where even the largest firms are of relatively small importance. According to Scitovsky,

> Monopoly and oligopoly consist of a power relation among the sellers or the buyers in a certain market; and this power relation depends largely on the number and size distribution of the competing sellers or buyers.[3]

Market reports and observations reflect that a number of changes have been taking place in Louisiana that affect the economic structure of milk markets in the state. Among these changes is a decrease in the number of firms operating in the markets and an increase in their average size. In the last decade, the number of milk processing and distributing firms has decreased 12 percent and the annual volume of milk sales has doubled. During the same period, the number of milk producers decreased 21 percent and average daily milk production more than doubled.

Most of the country milk-receiving stations have been closed and practically all producer-handlers have been eliminated in Louisiana. This fact is emphasized by market reports of only one producer-handler in the New Orleans, Louisiana, Market in 1962, while 310 operated in that market in 1940. There have also been horizontal mergers by firms in the industry and firms have increased their sales area.

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[1] This statement is supported by the following articles: National Bureau of Economic Research, *Business Concentration and Price Policy* (Princeton, New Jersey: Princeton University Press, 1955); R. B. Heflebower and G. W. Stocking, *Readings in Industrial Organization and Public Policy* (Homewood, Illinois: R. D. Irwin, Inc., 1958). Market structure may be defined as the competitive relationships existing among firms of an industry in a particular market.

[2] Gideon Rosenbluth, "Measures of Concentration," *Business Concentration and Price Policy* (Princeton, New Jersey: Princeton University Press, 1955), p. 57.

[3] Tibor Scitovsky, "Economic Theory and the Measurement of Concentration," *Business Concentration and Price Policy* (Princeton, New Jersey: Princeton University Press, 1955), p. 109.

These changes give rise to uncertainty as to the chances of survival of firms of varying sizes. Uncertainties, together with the problems associated with the effects of these rapidly changing conditions in the industry upon competitive behavior among firms, prompted this study.

Growth patterns, as they relate to stability, and the number and size distribution of firms are important elements of the problem. It is important to the dairy industry that the nature of these changes and their effect upon market structure be identified and evaluated. Such information will be useful to potential dairy firms as well as firms currently operating in the industry. Reliable knowledge of survival expectancies associated with firms of varying sizes and growth patterns would be helpful in the decision-making processes of firms in the industry. These problems are the substance of this study.

Purpose and Objectives

The major purpose of this study was to characterize and analyze the structural changes in fluid milk markets in Louisiana. The analysis relates to the changing number and size distribution of firms and the probable future structural developments. Specifically, the objectives may be stated as follows:

1. To characterize the structural changes in firms operating in the fluid milk markets in Louisiana, including both the producer and handler segments.
2. To estimate the number and size distribution of such firms in selected future time periods.
3. Using a dynamic concept of equilibrium, to estimate the number and size distribution of firms at an industry equilibrium (assuming that the observed tendencies will persist).
4. To derive an index of firm mobility in the market for both the handler segment and the producer segment.

Method of Analysis

The major analytical tool used in the quantitative analysis phase of this study was the Markov Chain process. Data requirements of the model are stringent; it requires information about the size of individual firms over time. In some cases such data are not available. In other instances firms frequently are reluctant to release them. These two factors tend to prohibit widespread use of the model. However, confidential data can often be obtained from original or alternative sources —including state and federal regulatory agencies—with sufficient assurances of the protection of confidence.

Louisiana's fluid milk industry is subject to state and federal market orders. Administrators of these orders are required to maintain audited records of milk sales by each firm in the market. Data used in the quantitative analysis were obtained from the Market Administrators. A procedure was devised whereby they could provide the necessary data for analysis with the Markov Process and still not violate the rules for releasing market data.[4]

Supplementary data for this study relating to number of firms and volume of milk production and sales were obtained from published reports of Market Administrators of the federal and state milk marketing orders in Louisiana. Other sources of data include the United States Census, State Experiment Station publications, and milk producer associations.

Scope

Most of the studies of the dairy industry to date that have used market structure models have been primarily concerned with the problem on a regional or national basis. Also, most of the economic studies dealing with business concentration in other segments of the economy have been on an industry rather than market basis.[5] A number of economists agree that the effects of business concentration are most significant in local markets. Moore and Clodius expressed it this way, ". . . changes in industrial concentration have their most direct effect on competition in local markets. Unfortunately, data on local market concentration are rather scarce."[6]

Another important economic factor omitted in most previous empirical studies of market structure was that of "countervailing power."[7] We know that in some respects, though not all, the effects of concentration in one segment of a market are offset in another segment of the market via "countervailing power."

This study approaches the problem from the standpoint of firm

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[4] For a discussion of the technique employed to obtain the data, see Appendix A.

[5] George J. Stigler, "Introduction," *Business Concentration and Price Policy* (Princeton, New Jersey: Princeton University Press, 1955), p. 3.

[6] F. R. Moore and R. L. Clodius, *Market Structure and Competition in the Dairy Industry* (Wisconsin Agricultural Experiment Station, Research Bulletin 233, March 1962), p. 26.

[7] J. K. Galbraith, *American Capitalism, The Concept of Countervailing Power* (Second Edition, revised; Cambridge, Massachusetts: The Riverside Press, 1956); Scitovsky, *op. cit.*, p. 112.

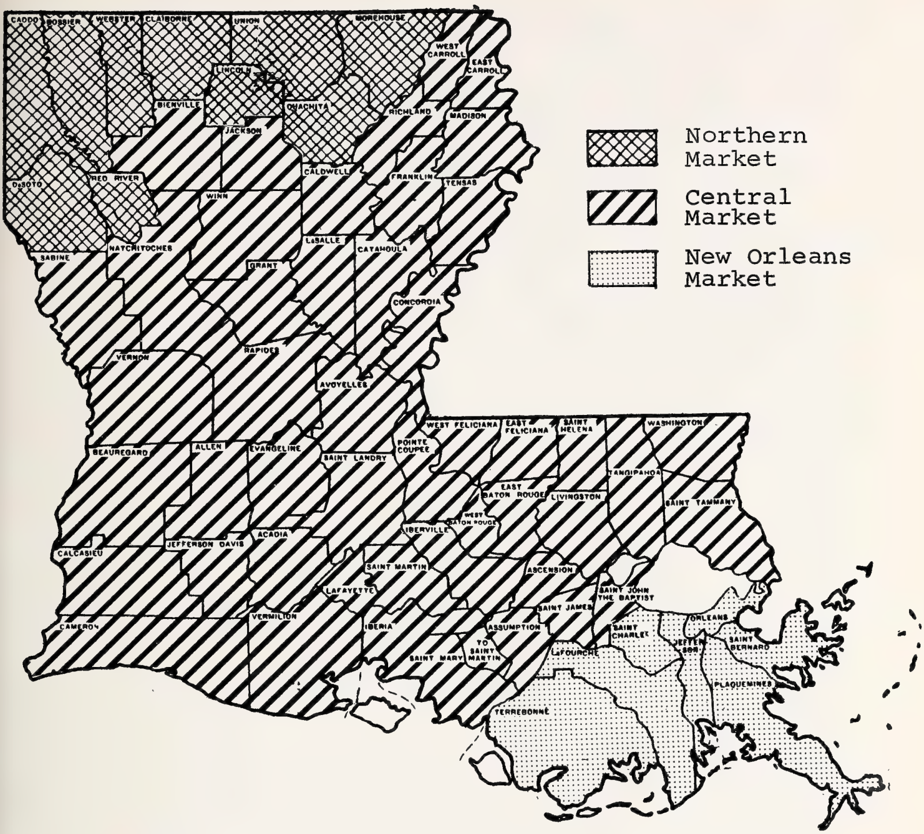

FIGURE 1.—Milk Marketing Areas of Louisiana.

size at the local fluid milk market level and considers both the production and processing segments of the market.

For purposes of analysis, Louisiana was divided into three marketing areas, namely, the (1) New Orleans, (2) Northern, and (3) Central Markets. The area for the first two markets, as shown in Figure 1, corresponds to the areas defined in Federal Orders No. 94 and No. 96, respectively. The Central Market corresponds to the area defined in Louisiana State Order No. 2, with the exception of the portion of that area included in the Northern Market.[8]

Both the Northern and the New Orleans geographic market areas have increased since 1955. However, all data used in this study, unless stated otherwise, have been adjusted to correspond to the expanded or modified market areas.

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[8] For a discussion of markets and market areas, see: D. C. Williams, Jr., *Optimum Distribution of Producer Milk Among Markets and Class Uses in Louisiana in 1959* (Unpublished M.S. thesis, Louisiana State University, Baton Rouge, Louisiana, 1960), pp. 13-22.

The processing facilities of milk handlers, in nearly all cases, were located within the market area where they were regulated. All producers, on the other hand, were not necessarily located within the marketing area covering the handler to whom they shipped.[9]

Unit for Measuring Size of Milk Handlers

Because of its importance a number of measures were considered to represent the size variable. Among the measures considered were the four principal dimensions of firm size—number of employees, sales, income generated, and assets.[10] After due considerations, the volume of milk sales was selected to represent firm size. The selection was based on the particular qualities of the variable and the availability of data.

Both total volume of packaged fluid milk sales and total volume of milk sales in all uses per time period were studied for use in establishing the distribution and for describing the size of milk handlers.[11] A likelihood ratio test indicated that either of the two units of measurement was equally good in measuring changes in size of respective firms. Since the principal outlet for milk in Louisiana was for fluid use, packaged fluid milk sales were used as the unit of measurement.[12]

Data were more readily available for individual firms on a monthly basis than on an annual basis. A correlation analysis was run to determine the reliability of data for a single month representing annual series. From a sample of 10 firms, a correlation analysis of annual sales with January (monthly) sales was found to be highly significant ($r = .9975$). Thus, it was considered that the use of volume of sales during the month of January would accurately indicate the size of firms for each year.

Unit for Measuring Size of Milk Producers

Established daily base in terms of average pounds of milk determined during the base-forming period was chosen as the measurement in determining the size criterion for analysis of the producer segment. The established daily base of a producer was the average milk delivery of such producer during a base-forming period.[13] The base-forming period for the markets in Louisiana was the fall and winter months. The base formed during this period was used in computing the producer's share of Class I sales during the base-operating period.[14]

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[9] For the location of milk plants and the location of producers that regularly deliver milk to handlers in Louisiana, see: Williams, *op. cit.*, pp. 29, 51, 124-130.

[10] M. A. Adelman, "The Measurement of Industrial Concentration," *Readings in Industrial Organization and Public Policy* (Homewood, Illinois: R. D. Irwin, Inc., 1958), p. 8.

[11] The terms "milk handler" and "fluid milk firm" are used synonymously.

[12] For a discussion of how milk is classified in Louisiana according to use, see: Howard P. Brosset, *Louisiana Annual Milk Marketing Report, 1961* (Baton Rouge, Louisiana: Louisiana Department of Agriculture and Immigration, Division of Milk Testing), p. iii.

LITERATURE REVIEW

Among the various techniques employed to analyze empirical data regarding the number and size distribution of firms, two of the most popular may be defined as (1) an absolute concentration ratio and (2) a percentage concentration ratio.[15] In the first definition, the measure of business concentration refers to the percent of total business activity controlled by a certain arbitrarily defined number of firms in the industry or market. Firm data are generally aggregated to conceal information of individual firms. The absolute concentration ratio is usually expressed as the percent of business controlled by the four largest firms. The second technique, on the other hand, expresses the share of business controlled by a given percentage of the firms. For example, 10 percent of the firms in the market account for 60 percent of the business activity in a particular product. A simple graphic presentation of the percentage concentration ratio may be shown by the use of a Lorenz curve. A hypothetical example of a Lorenz curve is illustrated in Figure 2. The area between the diagonal (the 45° line) and the curve, when expressed as a proportion of the total triangle beneath the diagonal, is called the Gini coefficient.[16] The Gini coefficient, as interpreted by Hart and Prais, is "a measure of average dominance in the group of firms and serves as a coefficient of inequality."[17]

Limitations of the Gini coefficient have been pointed out by Scitovsky. He objects to the use of the Gini coefficient because (1) it only gives an index of the inequality of size distribution and (2) it is not affected

---

[13] The terms "milk producer" and "milk producing firm" are used synonymously.

[14] For a discussion of Louisiana base plans, see: William H. Alexander and Albert Oretgo, Jr., *Operation of Base-Excess Plans Under State and Federal Regulations in Louisiana* (Louisiana Agricultural Experiment Station, D.A.E. Circular No. 212, August 1957).

[15] Among the discussions of measures of firm configuration with respect to the concentration of economic power, the following are included: P. E. Hart and S. J. Prais, "The Analysis of Business Concentration, A Statistical Approach," *Journal of the Royal Statistical Society* Series A, 119 (October 1956), pp. 150-175; Rosenbluth, *op. cit.*, pp. 57-59; M. A. Adelman, *op. cit.*, pp. 3-45; and Tibor Scitovsky, "Economic Theory and the Measurement of Concentration," *Business Concentration and Price Policy* (Princeton, New Jersey: Princeton University Press, 1955), pp. 101-113.

[16] M. A. Adelman, *op. cit.*, p. 4.

[17] Hart and Prais, *op. cit.*, p. 153.

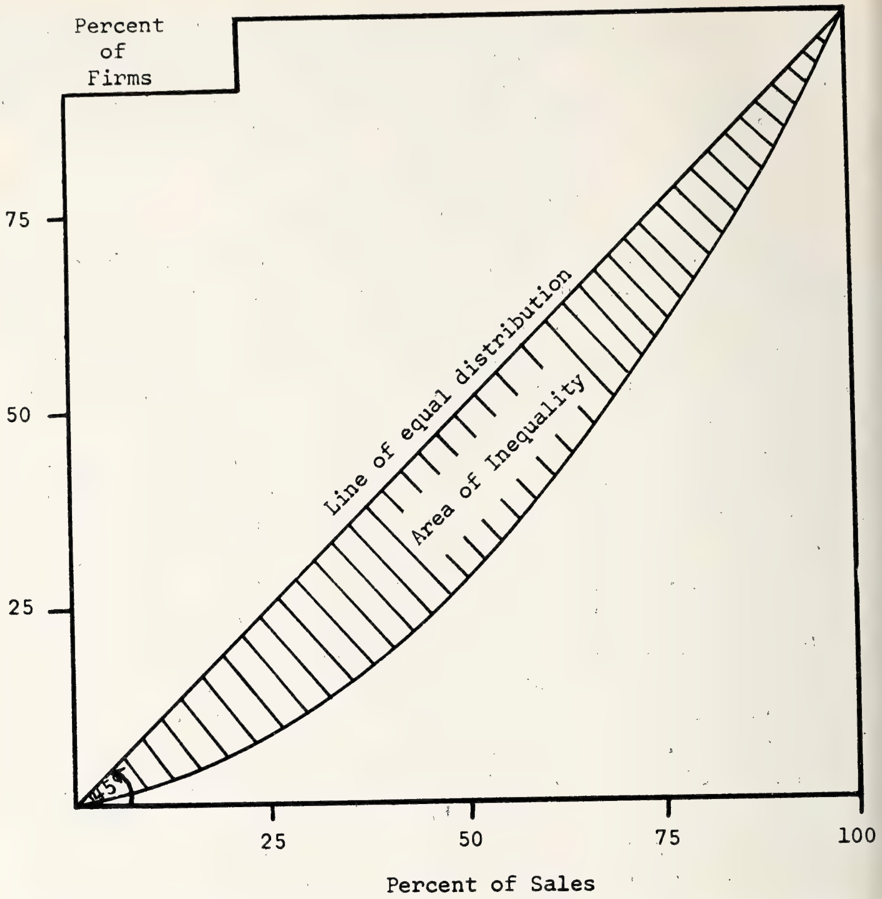

FIGURE 2.—A Hypothetical Example of a Lorenz Curve Reflecting Business Concentration.

by the total number of firms. He argues that the absolute number of firms is clearly relevant to monopoly power.[18]

Hart and Prais contend that the absolute concentration ratio has an advantage over the percentage concentration ratio, or a Gini coefficient, because it gives information in a form that is immediately suitable for assessing the market power, or the potential ability to exert monopolistic practices.[19] Where the market concerned consists of only a few firms, the nature of the market may well be described by giving the proportion of the market which is controlled by a specific number of the largest firms.

Rank correlation is another technique of analysis that has been used to measure movements of firms within size distributions.[20] The rank correlation coefficient provides a measure of change in the ordering of the firms from one time period to another. While a single coefficient computed by this method would have limited meaning, the computation of such coefficient for groups of firms, ranked according to the same criteria over several time periods, would yield a series of comparable and potentially useful coefficients. A series of coefficients computed by this method undoubtedly would give some indication of the increase or decrease in the rigidity of market structure.

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[18] Scitovsky, *op. cit.*, p. 113.

[19] Hart and Prais, *op. cit.*, p. 152.

In some cases rank correlation coefficients could be misleading. For example, suppose there are a large number of firms with significantly different sizes. A change in the order of the 10 largest firms, with the rank of other firms remaining constant, would give the same correlation coefficient as a change in the order of the 10 smallest firms, *ceteris paribus*. In effect, this method considers the economic power of each firm to be the same. But a given change in the ordering of the 10 largest firms is likely to have greater economic significance than the same change in the ordering of the 10 smallest firms.

An additional technique used to measure the effect of movements of firms among size groups is the Markov Chain. Reference has already been made to Padberg's use of the Markov Chain in studying the market structure of the dairy industry in California. N. R. Collins and L. E. Preston used the Markov Process in their study of the change in relative size of the 100 largest industrial firms and to project the equilibrium size distribution.[21] Hart and Prais also used this probabilistic approach in an investigation of business concentration.[22] Adelman employed Markov Chains in her analysis of the size distribution of firms in the steel industry.[23]

The Markov Chain process was selected because it apparently has several advantages over the other alternative techniques considered. The major advantages of the Markov Process are: (1) it measures the period to period changes in the position of individual firms within size categories, (2) it provides for the construction of an index of mobility, (3) it provides a meaningful way of measuring mergers,[24] and (4) it facilitates the evaluation of tendencies of structural development by using a dynamic concept of equilibrium to estimate the equilibrium distribution of firm size.

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[20] For an example of its use, see: N. R. Collins and L. E. Preston, "The Size Structure of Industrial Firms," *The American Economic Review,* LI (December 1961), p. 991.

[21] Collins and Preston, *op. cit.,* pp. 986-1003.

[22] P. E. Hart and S. J. Prais, *op. cit.,* pp. 150-175.

[23] I. G. Adelman, "A Stochastic Analysis of the Size Distribution of Firms," *Journal of the American Statistical Association,* LIII (December 1959), pp. 893-904.

[24] Mergers may be handled by dropping the acquired firm to a category of no production. The increase in size gained by the acquiring firm may dictate a movement of it to a different size category. Merger activity is considered in conjunction with all other forces affecting firm growth.

ANALYTICAL FRAMEWORK

Assumptions of the Markov Process: The basic assumptions of the Markov Chain process have been pointed out by Adelman,[25] Judge and Swanson,[26] and Kemeny, Snell, and Thompson.[27] The more important and critical assumptions as they apply to this study specifically are:

1. Firms that engage in the fluid milk industry can be grouped into size categories according to some criteria.
2. The evolution of a dairy firm through these size categories can be regarded as a stochastic process.
3. The probability of a firm's moving from one category to another is a function only of the two categories involved.
4. The transition probabilities (measure of a firm's ability to move from one category to another) remain constant throughout the evolutionary process.

The usefulness of this technique of analysis depends, at least partially, on how well these assumptions "fit" the "real world." Some points of frustration are as follows:

1. There is arbitrariness in defining the length and number of time periods used to observe firm growth patterns, and the allied decision of which period to use as the initial starting period. The starting period for this study is defined as the earliest period for which data were available; the growth patterns of firms were observed over the entire period for which data were available.
2. The assumption that a firm's size in time period "t+1" is conditioned only by its size in period "t" raises some question of reality when applied to the "real world." For example, the size of a firm which decides to plow back profits for a certain number of years in order to have capital to increase the size of plant could not, upon completion of the expansion program, be said to depend only on its size in the previous time period.

This objection may be partially overcome by choosing time intervals to minimize the effect of decision lags over more than one time period. An alternative would be to observe movements over several consecutive time periods.

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[25] I. G. Adelman, *op. cit.*, p. 894.

[26] G. G. Judge and E. R. Swanson, *Markov Chains: Basic Concepts and Suggested Uses in Agricultural Economics* (Illinois Agricultural Experiment Station, Research Report AERR-49, 1961), p. 6.

[27] Kemeny, Snell, and Thompson, *Introduction to Finite Mathematics* (Englewood Cliffs, New Jersey: Prentice-Hall, 1957), p. 171.

Fortunately the hypothesis that a firm's size in time "t+1" is dependent solely on time "t" may be tested statistically by the use of a Chi-square test.[28] In this study, independence was tested by Chi-square as presented by Snedecor.[29] The positive results of this test enhanced confidence of the acceptability of the assumption that a firm's size in a given time period depends on its size in the immediately preceding time period.

3. Any variable one selects to represent firm size is aggregative. All the economic forces which determine the growth pattern of firms in a given market obviously cannot be adequately represented by one variable—size. Although it is impossible to identify the effect of any particular component of this aggregate, the results of the aggregate of causal variables may be measured and evaluated. However, where firms can be placed into homogenous groups, transition matrices can be computed for firms in the different groups. Then, some indication of the effects of the different variables can be obtained.

4. The simplifying assumption of constant transition probabilities through time is necessary to estimate the equilibrium distribution. Adelman notes that such a procedure ". . . is analogous to that used in long-run comparative statics: That the forces which operate during the sample period will continue unchanged until equilibrium is reached."[30] By relaxing this assumption the equilibrium may be derived not as an estimate of the equilibrium, but as an analysis of the tendencies at work within the distribution.

A likelihood ratio test has been developed to test the hypothesis of no difference between transition probabilities between different time periods.[31] This test may also be used to test whether the set of factors determining transition probabilities for different markets is significantly different. Unfortunately, this test could not be employed in this study because the data were not available over a sufficient length of time to give more than one estimate of transition probabilities. However, the test was employed to test for differences in transition probabilities among markets.

5. If structural developments within a market are entirely the result

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[28] Judge and Swanson, *op. cit.*, p. 7.

[29] George W. Snedecor, *Statistical Methods* (Fifth Edition; Ames, Iowa: The Iowa State College Press, 1956), p. 225.

[30] I. G. Adelman, *op. cit.*, p. 894.

[31] T. W. Anderson, "Probability Models for Analyzing Time Changes in Attitudes," *Mathematical Thinking in the Social Sciences*, P. F. Lazarsfeld, editor (Glencoe, Illinois: The Free Press, 1954), p. 49; and Padberg, *op. cit.*, p. 197. Padberg developed transition probabilities for the dairy industry in California using two different five-year time intervals, 1950-1955 and 1955-1960. As a result of an erroneous calculation, he did not accept the hypothesis of no difference. The error was confirmed and corrected.

of actions by entrepreneurs of particular firms, their growth patterns may not be appropriately represented by a stochastic process. However, several factors in the fluid milk industry tend to have the effect of stochastic elements in growth patterns of competing firms. Technical progress, government regulations, labor unions, and the uncertainty that is associated with merchandising practices in today's imperfect fluid milk markets probably have this effect.

Definition and Operation of the Markov Process: The Mathematics of the Process

The Markov Chain model assumes that for any given sequence of experiments the outcome of each experiment depends on some chance event.[32] Thus, the process is stochastic. Kemeny defines a Markov Chain as:

> A finite stochastic process with outcome function f_0, f_1, . . . , f_n is a Markov Chain process if the starting state, given by f_0, is fixed and
>
> $$(1)\quad \Pr[f_n = t \mid (f_{n-1} = s) \wedge (f_{n-2} = r) \wedge \cdots \wedge (f_1 = a)] = \Pr[f_n = t \mid f_{n-1} = s]$$
>
> $$(2)\quad \Pr[f_n = t \mid f_{n-1} = s] = \Pr[f_m = t \mid f_{m-1} = s]$$
>
> for all $m \geq 1$, $n \geq 2$ and any possible sequence of outcomes a, . . . , s, t.[33]

This definition may be read as the probability of $f_n = t$ given $f_{n-1} = s$ and $f_{n-2} = r$ and so on.

This definition means that the results of a given experiment depend only on the result of the immediately preceding experiment and this dependence is the same at all stages, where stage refers to a particular place in the sequence of experiments.[34]

The application of this model involves the growth pattern of firms between specific size categories over given periods of time. From these observations a transition matrix of probabilities can be computed.

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[32] Judge and Swanson, *op. cit.*, p. 2.

[33] J. G. Kemeny, *et al.*, *Finite Mathematical Structure* (Englewood Cliffs, New Jersey: Prentice-Hall, 1959), p. 148. The equation numbers are the authors'.

[34] Another way of stating this definition is as follows: A series of consecutive time periods is required, each of which constitutes an experiment. A set of size categories (s_1, s_2, ... s_r) is also required. A firm can be in one—and only one—of these categories at a given time. Each firm is assumed to move between size categories each time period. Each move may be called a step. The probability that a firm moves from one category, s_i, to another s_j, depends only on its size before the move. The transition probabilities, p_{ij} (i.e., the likelihood that the firm will move from one size category, s_i, to another, s_j) are given for every ordered pair of categories. A starting category is specified at which the firm begins and an initial time period is specified in which the process starts. *Ibid.*, p. 148.

The effects of causal variables associated with firm growth between two subsequent time periods may be represented by a probability p_{ij}, where p_{ij} is the probability that a firm in size category s_i in a given time period (t) will be in size category s_j in the subsequent time period (t+1). These transition probabilities p_{ij} can be represented in a matrix P, with the subscripts i and j referring to rows and columns, respectively, where:

$$(3) \qquad \sum_{j=1}^{r} p_{ij} = 1, \text{ and } p_{ij} \geq 0.$$

The P_{ij}'s represent real numbers. Matrix P is of order r (i.e., matrices of transition probabilities are square) where r represents the number of size categories. In determining the elements p_{ij} of the transition matrix P, let a_{ij} represent the total number of firms that move from size category s_i to size category s_j during all time intervals (experiments). That is:

$$(4) \qquad P_{ij} = \frac{a_{ij}}{\sum\limits_{j=1}^{r} a_{ij}}$$

The distribution of firms at a given time period may be found by multiplying the distribution in the previous time period by the transition matrix P. For example,

$$(5) \quad C_{t_1} = C_{t_0} P,$$

where C is used to represent the number of firms per size category (i.e., $C = [c_{s_1}, c_{s_2}, \ldots c_{s_r}]$, where c_{s_1} = the number of firms in size category I, c_{s_2} = the number of firms in size category II, etc., and r represents the number of size categories) and the subscript of C denotes the time period. The expected relative distribution of number of firms in t_2 is obtained by multiplying C_{t_1} times P or C_{t_0} times P^2. In general

$$(6) \quad C_{t_k} = C_{t_{k-1}} P = C_{t_0} P^k.$$

If P is a regular stochastic matrix, one with some power having only positive components,[35] it will have the property that when raised in power[36] all rows tend to converge to a unique vector, K, where $K=k_1, k_2, \ldots, k_r$. This unique vector represents an equilibrium size distribution of firms that would be expected to result if the tendency observed should persist indefinitely.

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[35] For a more precise definition and discussion of regular stochastic matrices, see Kemeny, Snell, and Thomspon, *op. cit.*, p. 220.

Another approach to find the equilibrium row vector K is as follows: in equilibrium the distribution vector K must be invariant, i.e.,

$$(7) \quad K_{1xr}P_{rxr}=K_{1xr}$$

$$(8) \quad K_{1xr}[P\text{-}I]_{rxr}=0_{1xr}$$

where the subscripts denote the number of rows and columns, respectively, of the matrices. By transposing equation (8) we get

$$(9) \quad [P\text{-}I]'_{rxr}K'_{rx1}=0'_{rx1}$$

which is a set of r equations and r unknowns. Only r-1 of these equations are linearly independent and, therefore, any one of these equations may be dropped from the system. However, since K is a probability vector, we have

$$(10) \quad \sum_{j=1}^{r} K_{ij}=1$$

Using this information, equations (9) and (10) can be combined to form

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[36] The sum of any row of P is 1 for any power of P: i.e., $\sum_{j=1}^{r} p_{ij}=1$, for any i, 1 to r, for any power 1 to ∞ of P. This statement may be proved in general as follows: Let matrices

$$A_{mxn}B_{nxr} = C_{mxr} \text{ and}$$

$$\sum_{j=1}^{n} a_{ij} = 1, \text{ for any i, 1 to m, and}$$

$$\sum_{j=1}^{r} b_{ij} = 1, \text{ for any i, 1 to n.}$$

Then

$$\sum_{j=1}^{r} c_{ij} \text{ (for any i, 1 to m)} = \sum_{k=1}^{n} \quad \sum_{j=1}^{r} a_{ik}b_{kj} =$$

$$\sum_{j=1}^{r} a_{i1}b_{1j} + \sum_{j=1}^{r} a_{i2}b_{2j} + \cdots + \sum_{j=1}^{r} a_{in}b_{nj} =$$

$$a_{i1}\,1 + a_{i2}\,1 + \cdots + a_{in}\,1 = \sum_{j=1}^{r} c_{ij} = 1 \text{ (for any i, 1 to m).}$$

This information is useful as a check when raising probability matrices to powers.

a system of r linearly independent equations and r unknowns which can be solved for the values of the vector K.[37]

It is of interest to synthesize the equilibrium to evaluate the tendencies inherent in the observed movement of firms between size categories; this may be done by observing the nature of the equilibrium. To use this estimated equilibrium configuration as a prediction would require the employment of the explicit assumption that the observed tendencies will remain constant. As Judge and Swanson have pointed out, for regular Markov Chains the size distribution of firms in equilibrium does not depend on the initial relative distribution of firms among the categories, or the starting vector.[38] In other words, given the same transition probabilities, firms in a market will assume the same type distribution regardless of whether the market was originally competitive or oligopolistic. This results from the implication of the economic assumption of the model—that the future development of a firm is independent of its past history.

Since K represents the final probabilities of firms' being in each category, the equilibrium distribution of firms may be obtained by multiplying the number (N) of firms in the market in the initial time period times K;

$$(11) \quad N_{t_0} K = C_{t_\infty}.$$

The equilibrium distribution of firms generated by this model is rather unique in that it is both stationary and dynamic. It is stationary because the relative number of firms per size category does not change. It is dynamic in that firms may move between size categories. Adelman interprets an equilibrium structure in a firm-size model as that distribution from which the average number of firms entering a given category per period equals the average number of firms leaving it. Such a concept of equilibrium is thus stationary in nature for the market, and dynamic for the individual firm. In other words, equilibrium as used in this study does not imply that there is no movement of firms between categories. On the contrary, the stochastic conception of equilibrium explicitly requires that firms move in and out of each size category. But on the average, the forces acting to increase the number of firms in a given size category are exactly counterbalanced by those tending to decrease it.[39]

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[37] A technique for solving the system of equations is presented in Appendix B.

[38] Judge and Swanson, *op. cit.*, pp. 4 and 9.

[39] I. G. Adelman, *op. cit.*, pp. 895-896.

Mean Lifetime and Mobility of Firms

An index of firm mobility may be constructed by use of the transition matrix P to analyze the average number of time periods a firm is likely to remain in the same size category. The mobility index gives some indication of the rigidity of market structure. Hart and Prais agree that

> one may thus speak of industries that have a rigid structure and of those that have a mobile structure; industries that have both a high degree of concentration and a rigid structure are those in which one may suspect the existence of monopoly elements.[40]

Both the ease of movement by firms among size categories, as measured by this index, and the direction of movement, as determined from the transition matrix, have implications for analyzing problems at the firm level as well as at governmental levels. Simon and Bonini suggest that

> The same equilibrium distribution [of firms among size categories] may be produced with various degrees of mixing, . . . Public policy might be concerned with the amount of mobility rather than with the resulting degree of concentration. As a matter of fact, a measure of mobility (for firms or individuals) would appear to provide a better index of what we mean by "equality of opportunity" than do the usual measures of concentration.[41]

An estimating technique used by Adelman[42] and by Judge and Swanson[43] was employed to calculate the average number of time periods a firm is likely to remain in a given category. Let $c_{s_i t_o}$ be the number of firms in category s_i in the initial time period. Then, the number of these firms expected to be in the same category in the following time period is

$$(12) \quad c_{s_i t_1} = c_{s_i t_o} p_{ii},$$

$$c_{s_i t_2} = c_{s_i t_o} p_{ii}^2, \text{ and so on.}$$

Thus, the total time, T_i, spent in the s_i category by the $c_{s_i t_o}$ firms is

$$(13) \quad T_i = c_{s_i t_o} + c_{s_i t_o} p_{ii} + c_{s_i t_o} p_{ii}^2 + \cdots + c_{s_i t_o} p_{ii}^{n-1}$$

The average time, L_i, spent by a firm in category i may be obtained b dividing the above equation by $c_{s_i t_o}$; thus

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[40] Hart and Prais, *op. cit.*, p. 161.

[41] Simon and Bonini, *op. cit.*, p. 616. Brackets are by the authors.

[42] I. G. Adelman, *op. cit.*, p. 897.

[43] Judge and Swanson, *op. cit.*, p. 11.

$$(14)\quad L_i = \frac{T_i}{c_{s_i t_o}} = 1 + p_{ii} + p_{ii}^2 + \cdots = \frac{1}{1-p_{ii}},$$

The mean lifetime of a firm in a given category gives some indication of firm mobility, but it would be more meaningful if compared to some norm. Judge and Swanson[44] and Adelman,[45] following the works of Prais,[46] used a perfectly mobile industry as a standard of comparison. They define a perfectly mobile market as one for which the probability that a firm will move from category A to category B during a single time interval is independent of A. In other words, the probability of a firm's moving to a specified size category in one time period is the same for all firms regardless of its size before the move. By this definition, each column of the transition matrix of r size categories for a perfectly mobile market is composed of r identical positive coefficients, and the sum of the elements of each row is unity. The matrix P raised to the infinite power gives a matrix that may be called T that fulfills these requirements.[47] Each row of the matrix T would be the same as the unique vector K. Given the transition matrix P and the equilibrium matrix T, the index for market mobility for time t_k may be written as[48]

$$(15)\quad I_{t_k} = \frac{\displaystyle\sum_{i=1}^{r} \frac{k_{ii}}{1-k_{ii}}}{\displaystyle\sum_{i=1}^{r} \frac{p_{s_i t_k}}{1-p_{ii}}}$$

where k_{ii} represents the elements of matrix T and $P_{s_i t_k}$ denotes the percentage of the total number of firms in s_i at time t_k.

Absorbing Markov Chains

When it is impossible for firms to move from a category, s_i, it is called an absorbing category. Specifically, s_i is an absorbing category when $p_{ij}=1$, where $i=j$. If (1) there is at least one absorbing s_i, and (2) it is possible to go to an absorbing s_i from every transient or nonabsorbing s_i (not necessarily in one step), the Markov Chain is absorbing. It follows then that in an absorbing Markov Chain the probability that the process will be absorbed is 1.[49]

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[44] *Ibid.*

[45] I. G. Adelman, *op. cit.*, p. 897.

[46] S. J. Prais, "Measuring Social Mobility," *Journal of the Royal Statistical Society*, Series A, 118 (1955), pp. 56-66.

[47] Judge and Swanson, *op. cit.*, p. 11.

[48] I. G. Adelman, *op. cit.*, p. 897.

[49] Kemeny, *et al.*, *op. cit.*, p. 404; and Kemeny, Snell, and Thompson, *op. cit.*, pp. 326-327.

Kemeny, *et al.,* suggest that the three following questions about absorbing Markov Chains are of interest: (1) Where there is more than one absorbing category in the transition probability matrix, what is the probability that firms will end up in a given absorbing category? (2) On the average, how many time periods will a firm be in each nonabsorbing category? (3) On the average, how many time periods will it take for the process to be absorbed? For a technique (including examples) to solve questions of this nature, the reader is referred to Kemeny, *et al.*[50]

ANALYSIS OF STRUCTURAL CHANGES IN FLUID MILK FIRMS IN LOUISIANA

A number of changes have been taking place with respect to the number and size of milk handlers in Louisiana. This is partially reflected in Table 1. In general, the number of firms has been decreasing and the average size of the remaining firms has been increasing. There were, for example, 83 handlers in Louisiana in 1952 with average annual sales of 6.7 million pounds. By 1961, the number of handlers had decreased to 73, and the average sales per handler had doubled.

Producer-handlers have almost disappeared in Louisiana. In 1962, there were six producer-handlers in the Central Market, two in the Northern Market, and only one in the New Orleans Market. This number represents a decline from 310 producer-handlers in the New Orleans Market alone in 1940.[51] Also, the nine milk cooling stations in 1962 were only 69 percent as many as existed in 1953 (Table 1).

For analytical purposes, arrays were made of fluid milk distributing firms on the basis of packaged fluid milk sales. Because of the confidential nature of the data, these arrays were made in groups of three firms. For example, group one represents the three firms with the largest volume of sales in the market and group two represents the next largest three, and so on (Appendix Tables 2-5).

These data were used to indicate the degree of concentration of fluid milk sales by handlers in each market. Lorenz curves from these data indicate very little change in the percentage of firms over the period of time for which data were available[52] (Figure 3).

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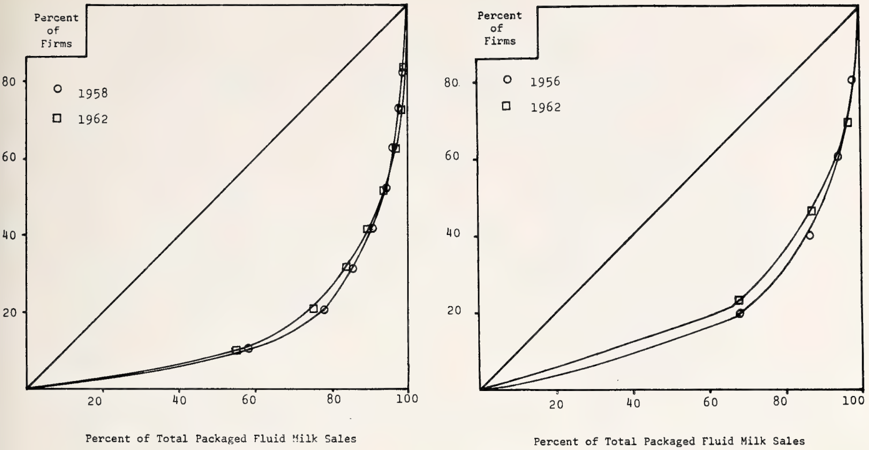
[50] Kemeny, *et al., op. cit.,* pp. 404-409.

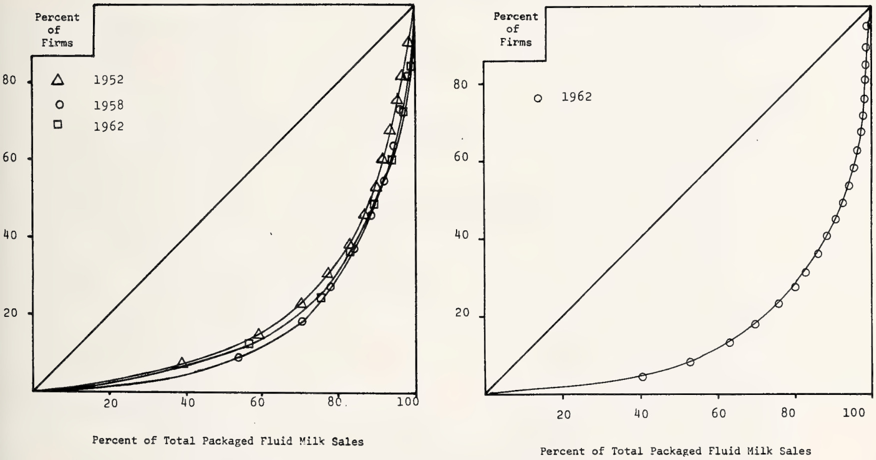
[51] *Compilation of Statistical Material Concerning Order No. 42, as Amended, Regulating the Handling of Milk in the New Orleans, Louisiana Marketing Area* (Office of the Market Administrator, November 1947).

[52] The Gini coefficient was not used to compare the distributions because this coefficient is derived from the entire Lorenz curve, and the results of this study involve the estimation of a limited number of points. Although a smooth curve was fitted to the data, the computation and presentation of the Gini coefficient might convey an impression of accuracy exceeding that justified by the data.



New Orleans Market

Northern Market



Central Market

Three Markets Combined

FIGURE 3.–Cumulative Size Distribution of Fluid Milk Firms, Louisiana Markets, January of Selected Years. (Source: Appendix Tables 2 - 5.)

Comparisons made by the Lorenz curves for the different markets show the degree of variation in firm sizes is greatest for the New Orleans Market. However, since the Lorenz curves consider the percentage of firms instead of the number of firms, these results could be misleading. The Northern Market had the smallest number of firms and the big three in that market accounted for the greatest percentage of milk sales when compared with other Louisiana markets.

Although the Central Louisiana Market included a geographic area over three times as great as either the Northern or New Orleans Market, the Lorenz curves indicate that the inequality of firm size for that

TABLE 1.—Number and Size of Milk Handlers, Number of Producer-Handlers and Milk Cooling Stations, Louisiana Milk Markets, 1951-1962

Year	New Orleans			Northern Louisiana*		
	Handlers		Producer-handlers	Handlers		Producer-handlers
	Average number	Average size total sales***		Average number	Average size total sales***	
	Per month	*Mil. lbs. per year*	*Number*	*Per month*	*Mil. lbs. per year*	*Number*
1951	25	9.9	NA	17	6.6	NA
1952	26	10.1	NA	16	7.3	NA
1953	25	11.2	8	15	8.4	3
1954	26	11.6	NA	15	8.8	NA
1955	29	10.9	NA	15	9.3	NA
1956	28	12.5	NA	16	9.7	NA
1957	27	13.1	4	15	11.7	4
1958	33	11.2	NA	13	13.5	NA
1959	32	11.9	5	13	13.5	3
1960	32	13.0	NA	13	14.7	NA
1961	32	14.4	NA	13	13.9	NA
1962****	29	NA	1	13	NA	2

(Continued)

TABLE 1.—(Continued)

Year	Central**			Three Markets Combined			
	Handlers		Producer-handlers	Handlers		Producer-handlers	Cooling stations
	Average number	Average size total sales***		Average number	Average size total sales***		
	Per month	*Mil. lbs. per year*	*Number*	*Per month*	*Mil. lbs. per year*	*Number*	*Number*
1951	44	3.8	NA	86	6.1	NA	NA
1952	41	4.6	NA	83	6.7	NA	NA
1953	37	5.4	24	77	7.8	35	13
1954	37	6.1	NA	78	8.3	NA	NA
1955	39	6.1	NA	83	8.2	NA	NA
1956	39	6.6	NA	83	9.0	NA	NA
1957	39	8.6	12	81	10.3	20	13
1958	34	9.1	NA	80	10.5	NA	NA
1959	29	10.0	17	76	11.0	25	11
1960	28	10.8	NA	73	12.3	NA	NA
1961	28	13.2	NA	73	13.5	NA	NA
1962****	26	NA	6	68	NA	9	9

*Prior to August 1958, data for the Shreveport (or Northwest) and Northeast Louisiana marketing areas were summed. Since August 1958, the combined areas constituted the Northern Louisiana marketing area under Federal Order No. 66.

**Data as reported for the Central, Southwest, and Southeast areas were combined to represent the Central Louisiana Market.

***Computed by dividing the average number of handlers per month into total sales in the market for the year.

****January.

NA—Not available.

Source: *Louisiana Annual Milk Marketing Report* (Baton Rouge, Louisiana: Louisiana Department of Agriculture and Immigration, Division of Milk Testing) and *Milk Processing Plants in Louisiana* (Baton Rouge, Louisiana, Louisiana Department of Agriculture and Immigration, Division of Milk Testing, 1953, 1957, 1959, and 1962).

market was approximately the same as for the Northern Market. During January 1962 the three largest fluid milk firms in Louisiana accounted for 40 percent of the total packaged fluid milk sales in the state (Appendix Table 5). The six largest firms accounted for slightly more than half of the total packaged fluid milk sales. Fifteen handlers accounted for 75 percent of the sales. This means that 25 percent of the total packaged fluid milk sales were divided among 52 firms, or 78 percent of the firms. These data are also shown in the form of a Lorenz curve in Figure 3. Data required for such an analysis were not available for prior years.

Evaluation of Movements of Fluid Milk Firms Among Size Categories

Movements of Firms Among Size Categories

The general operation of the Markov Process includes observing the period-to-period growth pattern of each firm in terms of movements among specific size categories over given periods of time. Movements were observed and analyzed within the framework set forth in a previous section. Volume of packaged fluid milk sales per month was used to represent firm size (Table 2). In any one time period it was possible for a firm to be in only one of the seven specific size categories.

TABLE 2.—Ranges of (Unequal) Size Categories Used in the Analysis of Growth Patterns of Fluid Milk Firms

Size category	Category limits
	Thousand pounds per month
S_0	0
S_1	1-100
S_2	101-250
S_3	251-400
S_4	401-750
S_5	751-3,000
S_6	> 3,000

Time intervals of one year were chosen for the analysis. It seems that the greater number of observations possible under this choice would yield a better estimate of transition probabilities and tend to counterbalance any advantages that might occur by using longer time intervals.

Data for the observation of firm movements for the New Orleans Market were available only for the years 1958 through 1962. Data for the other two markets were available from 1956 through 1962. Hence observations were available for four movements among size categories of each firm in the New Orleans Market and six movements of each firm in the other markets.

The movements of firms among size categories are recorded in Table 3. In this table, S_i represents the size category in a given year and is indicated on the left side of the table, and S_j represents the size category in the following year and is indicated across the top. The elements, A_{ij}, of the table represent the total number of firms that moved from S_i to S_j during all time intervals. For example, observe the second row in Table 3 for the New Orleans Market. There were two firms that moved from S_1 to S_0, or that went out of business from category S_1.

TABLE 3.—Movements of Milk Handlers Among Size Categories as Reflected by Packaged Fluid Milk Sales, Louisiana Markets, 1956 through 1962

Size category in given year	Size category in following year						
	S_0	S_1	S_2	S_3	S_4	S_5	S_6
NEW ORLEANS MARKET*							
S_0	10	1			1	1	
S_1	2	36	1				
S_2	1	1	15	1			
S_3			1	15	2		
S_4				1	14		
S_5						13	
S_6							12
NORTHERN LOUISIANA MARKET							
S_0	20	3					
S_1	3	1	3		1		
S_2	1	1	13	5			
S_3	1		3	7	2		
S_4			1		9	1	
S_5						17	1
S_6						1	8
CENTRAL LOUISIANA MARKET							
S_0	48	3	1			1	
S_1	10	23	3				
S_2	2	7	41	8	1		
S_3	2		4	10	5		
S_4				3	30	1	
S_5	1				1	35	
THREE MARKETS COMBINED							
S_0	78	7	1		1	2	
S_1	15	60	7		1		
S_2	4	9	69	14	1		
S_3	3		8	32	9		
S_4			1	4	53	2	
S_5	1				1	59	1
S_6						1	26

*Data on movements of firms among size categories were available for the New Orleans Market only from 1958 through 1962.

Source: Office of the Milk Marketing Administrators, New Orleans, Shreveport, and Baton Rouge, Louisiana.

There were 36 observations of firm movements from S_1 to S_1, or no change in size category. And, one firm increased in size from S_1 to S_2.

Chi-square test procedures were employed to test the hypothesis that a firm's size in a given year (t+1) was independent of its size in the previous year (t).[53] Since these computed Chi-square statistics exceeded the theoretical tabular values at the 99 percent confidence level, the hypothesis of independence was rejected. In effect the rejection of this hypothesis increases the credence of the acceptability of the assumption that a firm's size in a given period depends on its size in the immediately preceding period.

Transition Probabilities for Fluid Milk Firms

Before deriving the transition probabilities, a size category, S_0, was specified with no production (no sales). This category was provided to allow for entry into and departure from the markets by firms. Provision of this category made it necessary to provide a reservoir of potential entrants into the system. Data were not available on the number of potential entrants. Thus, it became necessary to estimate the number of potential entrants into the system. Ten times the number of firms that were active in the initial year of observation, t_0, was used to establish a number for potential entrants for each market.[54] This somewhat arbitrary selection does not affect the economically relevant portion of the results. Proof of this statement will be discussed later.

The transition probabilities shown in Table 4 were calculated from the observed year-to-year movements among size categories by fluid milk firms presented in Table 3 adjusted for potential entrants. One size category, S_6, was omitted from the transition matrix for the Central Market, because of the small number of firms in the larger size categories.

The transition probability matrices give some insight into the dynamic aspects of milk sales. The coefficients in the cells of the transition matrices give the probability of movement by firms from each of the size categories indicated on the left side to each of the size categories indicated across the top in Table 4. For example, according to the experience of packaged fluid milk sales by handlers in the New Orleans

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[53] This was in effect a measure of the applicability of the assumption of the model that "the probability of moving from one category to another is a function only of the two categories involved." The value of the test computed for each market was as follows: New Orleans Market, 599.6 with 36 degrees of freedom; Northern Louisiana Market, 315.9 with 36 degrees of freedom; Central Louisiana Market, 660.6 with 25 degrees of freedom; and the three markets combined, 1,818.4 with 36 degrees of freedom.

[54] In the section dealing with milk producers, it was assumed that every farm in the supply area for a market was a potential dairy farm. The total number of farms in the supply area for the New Orleans Market, less commercial milk producers in the area, was about 10 times the number of dairy farms.

TABLE 4.—Transition Probability Matrix of Fluid Milk Firms as Reflected by Packaged Fluid Milk Sales, Louisiana Markets

	S_0	S_1	S_2	S_3	S_4	S_5	S_6
				NEW ORLEANS MARKET			
S_0	.997129	.000957			.000957	.000957	
S_1	.051282	.923077	.025641				
S_2	.055556	.055556	.833332	.055556			
S_3			.055556	.833333	.111111		
S_4				.066667	.933333		
S_5						1.000000	
S_6							1.000000
				NORTHERN LOUISIANA MARKET			
S_0	.996346	.003654					
S_1	.375000	.125000	.375000		.125000		
S_2	.050000	.050000	.650000	.250000			
S_3	.076923		.230769	.538462	.153846		
S_4			.090909		.818182	.090909	
S_5						.944444	.055556
S_6						.111111	.888889
				CENTRAL LOUISIANA MARKET[1]			
S_0	.997386	.001568	.000523			.000523	
S_1	.277778	.638889	.083333				
S_2	.033898	.118644	.694916	.135593	.016949		
S_3	.096238		.190476	.476191	.238095		
S_4				.088235	.882353	.029412	
S_5	.027027				.027027	.945946	
				THREE MARKETS COMBINED			
S_0	.997089	.001852	.000265		.000263	.000529	
S_1	.180723	.722892	.084337		.012048		
S_2	.041237	.092784	.711340	.144330	.010309		
S_3	.057692		.153846	.615385	.173077		
S_4			.016667	.066667	.883333	.033333	
S_5	.016129				.016129	.951613	.016129
S_6						.037037	.962963

[1] Because of the small number of firms in the largest categories for the Central Market, only five categories were used for computing this matrix.

Blank cells represent zero coefficients.

Market, the probability that a firm in category S_1 in a given year will remain in the same category the next year was .923077. The probability of going out of business, or having no sales in the market, was .051282, and the probability of increasing sales to S_2 was .025641. The nature of the model requires that the sum of the probabilities in each row equal 1.0. Where one cell, P_{ij}, in a matrix contains the figure 1.0, it represents a case where firms in that category did not increase or decrease their sales beyond the limits of the specific category.

The magnitude of entries in the cells on the main diagonal indicate there was a strong tendency for firms to remain within a given size category from one year to the next. The probabilities on the diagonal are all larger than any of the other elements in each row for each market, with the exception of the Northern Market. This rigidity is partially due to the size category intervals and length of time periods used in the analysis. Smaller ranges would have permitted smaller year-to-year changes in the volume of sales by milk handlers to result in a movement.

The calculated likelihood of a firm's increasing in size can be compared with the likelihood for a decrease in size for firms in any given category. The aggregative values obtained by summing the elements to the right of the diagonal represent the likelihood for increases; conversely, the sum to the left of the diagonal represents the likelihood for decrease. Observe, for example, the transition matrix for packaged fluid milk sales by handlers in the Northern Market. For size category S_1 the probability of a firm's decreasing in size is .375, while the probability of increasing in size is .500 (.375+.125). Thus, the probability that the firm will increase in size is greater than the probability for a decrease in size.

Some important general observations can be made from the data. First, there is a tendency for small firms to get smaller or go out of business. Second, there is a strong economic pull for firms remaining in the market to increase in size. The probability of a firm's going out of business decreases as the size of the firm increases. Once a firm reaches size category S_4 the chances of its going out of business are rather remote. The Central Market is the only one where any firms in a size category greater than S_3 went out of business during the time period under study. Also, the most probable outcome—excluding remaining in the same category—is that firms either increase or decrease in size by one category at a time.

For firms entering the Central and Northern Markets, the calculated probability is greatest that they will enter in the smallest active category, S_1. On the other hand, for firms entering the New Orleans Market, the probability is equally great that they will enter in a size category larger than S_1.

The null hypothesis of no difference between markets in transition probabilities was tested by the likelihood ratio test. This hypothesis was not rejected at the 5 percent level. This means that, statistically speaking, factors affecting movements of fluid milk firms among size categories were not significantly different among the three markets.

Equilibrium Distribution of Fluid Milk Firms

The equilibrium distribution in this study was synthesized not as a forecast of what the future state of the markets would be, but rather as an evaluation of the tendencies inherent in the observed movements of firms between size categories.

Equilibrium distributions of fluid milk firms were synthesized for each market by deriving the equilibrium vector K, where K represents the relative distribution of firms among size categories in equilibrium, ($K = k_0 k_1 k_2 \ldots k_r$). These distributions are presented in Table 5 along with the distribution in the initial year of observation and the estimated distributions for 1972.

In equilibrium, the distribution of economic importance is the rela-

TABLE 5.–Percentage of Fluid Milk Firms in Each Size Category as Reflected by Packaged Fluid Milk Sales, in the Initial Year of Observation, and Estimates for 1972 and Equilibrium, Louisiana Markets

Year	Size category						
	S_0	S_1	S_2	S_3	S_4	S_5	S_6
	– – – – – – – – – – – – – *Percent* – – – – – – – – – – – – –						
	NEW ORLEANS MARKET*						
1958	–	34.5	17.3	17.2	10.4	10.3	10.3
1972	–	23.4	10.0	13.3	23.3	20.0	10.0
	NORTHERN LOUISIANA MARKET						
1956	–	33.4	13.3	13.3	13.3	20.0	06.7
1972	–	07.7	15.4	07.7	15.4	38.4	15.4
Equilibrium	–	0	0	0	0	66.7	33.3
	CENTRAL LOUISIANA MARKET**						
1956	–	20.0	42.9	08.6	11.4	17.1	
1972	–	10.0	15.0	10.0	35.0	30.0	
Equilibrium	–	12.3	12.3	05.5	23.4	46.5	
	THREE MARKETS COMBINED***						
1956	–	21.3	26.7	16.0	13.3	14.7	08.0
1972	–	13.3	13.3	10.0	25.0	28.4	10.0
Equilibrium	–	10.3	08.7	06.6	19.5	38.2	16.7

*Because of the fact that the transition matrix for the New Orleans Market had absorbing states in categories S_5 and S_6 and it was possible for firms in each nonabsorbing category to be in an absorbing category in equilibrium, the active firms would be only in these two categories. Because of the inability to determine the actual number of potential firms, the equilibrium distribution of the firms between these two categories was not estimated.

**Only five categories were used for the Central Market because of the small number of firms in the larger categories.

***These estimates were based upon the transition matrix calculated from the observed growth pattern for all firms in Louisiana (the consolidation of observations for the three markets).

tive distribution of firms actually selling milk in the market. This relationship was derived by normalizing the results so that $\sum_{J=1}^{r} k_j = 1$. This distribution is independent of the number chosen to represent potential fluid milk firms, where the transition matrices are regular stochastic matrices.[55]

In equilibrium, 67 percent of the firms in the Northern Market would be in S_5 and 33 percent in S_6. The equilibrium position indicated for the Central Market and the three markets combined would be such that about half of the firms would be larger than size S_4. Also, in equilibrium the largest percentage of firms would be in S_5 in each of the markets.

The estimated distribution of firms for 1972 shows a tendency to approach the equilibrium distribution. In general, S_1, S_2, and S_3 decreased relatively while S_4, S_5, and S_6 increased as compared to the initial observed distribution.

If a transition matrix is an absorbing matrix with more than one absorbing category, the number of potential entrants may directly affect the equilibrium distribution. The transition matrix calculated for the New Orleans Market is an absorbing matrix of this nature. Thus, because of inability to determine the actual number of potential milk handlers, the equilibrium for the New Orleans Market was not included in Table 5.

Even though an exact equilibrium distribution was not estimated for the New Orleans Market, some observations are possible regarding equilibrium. In the observed movements of firms among size categories in the New Orleans Market, firms moved in and out of each category except S_5 and S_6. Also, firms moved into but not out of S_5. Furthermore, there were no movements into or out of S_6. Therefore, categories S_5 and S_6 in the transition matrix (Table 4) for the New Orleans Market were absorbing categories, and the probability of absorption in S_5 was 1.0 for firms starting in each nonabsorbing category. Thus, all firms not currently in S_5 and S_6 would ultimately be absorbed in S_5. In equilibrium under these conditions, there would be three firms in S_6 (the number of firms in S_6 in the initial year of observation), and the number of firms in S_5 would depend upon the actual number of potential entrants.

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[55] Adelman presents proof of this statement in the form of the schematic solution for k_j by determinants. See: I. G. Adelman, *op. cit.,* p. 901.

A regular stochastic matrix may be defined as follows: "A stochastic matrix is said to be regular if some power of the matrix has only positive components." Kemeny, Snell, and Thompson, *op. cit.,* p. 220.

Fluid Milk Handlers Estimated for 1972

Estimates of the number of firms that would be expected in each size category in 1972 were calculated and are shown in Table 6. Except in the case of an absorbing matrix, these elements are not affected by the number selected to represent a reservoir of potential entrants (see footnote 55, page 30). The estimates of 13 firms for the Northern Market and 20 for the Central Market represent a decrease of 13 and 43 percent, respectively, from the actual number in 1956. The number estimated for the New Orleans Market in 1972 was 30, an increase of 3 firms from the initial time period.

The model indicates that the trend toward smaller absolute number of firms in the industry will continue. It indicates that by 1972 there will be 21 percent fewer handlers in the three markets combined than in 1956, or only about 60 milk handlers in Louisiana. This represents a decrease of 13 firms from the number in operation during 1956. Sixty-three percent of the firms operating in 1972 would be in the largest three categories. The largest number of firms in a single size category would be 17 in S_5. Thirty-eight firms would be in size categories larger than S_3. Only 8 firms would be in S_1.

The estimates for 1972 suggest that in all Louisiana markets, except New Orleans, there would be a larger relative and absolute number of firms in S_5 in 1972 than existed in time period t_0. On the other hand, the number of firms in categories S_1, S_2, and S_3 would be smaller in 1972 for each market than the number in t_0. An exception would be size category S_2 in the Northern Market, which shows no change.

TABLE 6.—Estimated Number of Fluid Milk Firms per Size Category, Louisiana Markets, 1972

Size category							Total
S_0	S_1	S_2	S_3	S_4	S_5	S_6	
			Number				
			NEW ORLEANS MARKET				
–	7	3	4	7	6	3	30
			NORTHERN LOUISIANA MARKET				
–	1	2	1	2	5	2	13
			CENTRAL LOUISIANA MARKET				
–	2	3	2	7	6	–	20
			THREE MARKETS COMBINED*				
–	8	8	6	15	17	6	60

*The estimates for each market, including the three markets combined, were developed from four separate transition probability matrices. Because of this procedure, the number of firms for the state distribution (three markets combined) may not equal the sum of the firms estimated in individual markets.

Mobility of Fluid Milk Firms

The size of the calculated coefficients in the principal diagonal cells of the transition matrix is positively correlated with the degree of rigidity or stability in the market structure. Comparisons of the relative stability of milk sales in the different markets may be made using the data in Table 4. The same data were used to estimate the mean number of years spent in each size category by an average milk handler (Table 7). The mean lifetime of firms in category S_0 was omitted from the table. This omission does not affect the index for the other categories. However, if the number of potential entrants had been known, it would have been useful to compute the value for this category, since it would have provided a quantitative indication of barriers to entry. The mean lifetime for firms in the perfectly mobile market[56] was computed from the normalized equilibrium vector K.

TABLE 7.–Mean Lifetime of a Fluid Milk Firm in a Specified Size Category, Louisiana Markets

Size category	Mean lifetime		Ratio
	1958-62 average	Perfectly mobile market	
	NEW ORLEANS MARKET		
S_1	13.0	–	–
S_2	6.0	–	–
S_3	6.0	–	–
S_4	15.0	–	–
S_5	∞	–	–
S_6	∞	–	–
	NORTHERN LOUISIANA MARKET		
	1956-62 Average		
S_1	1.1	–	–
S_2	2.9	–	–
S_3	2.2	–	–
S_4	5.5	–	–
S_5	18.0	3.0	6.0
S_6	9.0	1.5	6.0
	CENTRAL LOUISIANA MARKET		
S_1	2.8	1.1	2.5
S_2	3.3	1.1	3.0
S_3	1.9	1.1	1.7
S_4	8.5	1.3	6.5
S_5	18.5	1.9	9.7
	THREE MARKETS COMBINED		
S_1	3.6	1.1	3.3
S_2	3.5	1.1	3.2
S_3	2.6	1.1	2.4
S_4	8.6	1.2	7.2
S_5	20.7	1.6	12.9
S_6	27.0	1.2	22.5

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[56] "Perfectly mobile market" defined on page 19.

The mean lifetime of firms in a perfectly mobile market for the New Orleans Marketing Area was not presented in Table 7. This omission may be explained by the fact that in equilibrium there would be no firms in categories S_1, S_2, S_3, and S_4 because of the nature of the absorbing categories in the transition matrix for that market. Likewise, in equilibrium there would be no firms in the first four categories in the Northern Market. Furthermore, there would be no movement out of categories S_5 and S_6 in the New Orleans Market, and obviously the mean lifetime would be infinity for firms in those two categories. On the other hand, there could be movements of firms between categories S_5 and S_6 in the Northern Market.

In the Central Marketing Area and for the three markets combined, the mean lifetime of firms conforms more closely with the perfectly mobile market concept. The movements of firms in these two markets indicate that firms become less mobile upon reaching size S_5. The highest mobility of firms was observed in S_3.

There was a wide diversity in the observed mean lifetime for firms in different size categories and in different markets. For example, firms remained in S_1 in the Northern Market an average of 1.1 years. On the other hand, firms in S_5 and S_6 in the New Orleans Market would be expected to remain indefinitely in their respective size categories. Firms in S_3 were more mobile than firms in the other categories, except in the Northern Market. In general, the data in Table 7 indicate that firms in the largest categories are less mobile than those in other size categories. These results indicate that the economic forces for milk handlers to change size categories decrease as the firms become larger.

Market mobility indices that give the relationship of the mobility of firms in a market in selected time periods to the mobility under the concept of a "perfectly mobile structure" were computed (Table 8). The mobility of firms in the Northern Market in 1956 was 45.8 percent

TABLE 8.—Market Mobility Indices, Louisiana Milk Markets, 1956, 1972, and Equilibrium

Market	Index of mobility		
	1956	1972	Equilibrium
New Orleans*	—	—	—
Northern Louisiana	45.8	29.0	20.2
Central Louisiana	24.2	16.0	13.2
Three Markets Combined	15.9	11.3	9.0

*An index of mobility is not presented for the New Orleans Market because the transition matrix for that market represents the process of an "absorbing chain." However, this phenomenon and a comparison of the indices computed for the three markets combined with those for the other two markets suggest that firms in the New Orleans Market are the least mobile.

of that in a perfectly mobile structure. By 1972 the mobility of firms in that market would be reduced to about 29 percent of the expected value in a "perfectly mobile structure."

The mobility of firms in each of the markets in Table 8 was approximately one and one-half times as great in 1956 as the estimated mobility in 1972 and about twice as great in 1956 as in equilibrium. These indices suggest the existence of a consistent decrease in the mobility of fluid milk handlers in these markets.

An index of market mobility was not computed for the New Orleans Market because the transition matrix represents the process of an "absorbing chain." However, a study of Tables 7 and 8 indicates that the structure of the New Orleans Market was more rigid than the other two markets.

This analysis shows a tendency for a larger proportion of the fluid milk handlers to gravitate to the least mobile, larger size categories. The combined influence of the transition of firms to the larger size categories and the tendency for a decrease in firm mobility produces a more rigid market structure.

ANALYSIS OF STRUCTURAL CHANGES IN MILK PRODUCING FIRMS IN LOUISIANA

In a dynamic economy, milk producers, like other firms, adjust their size, or scale of operation, in response to such economic and environmental factors as changes in prices, government support programs, and technology.

During the last decade, such adjustments have been reflected largely by a decrease in the number of dairy farmers and a concurrent increase in the average size of enterprise. In 1952, an average of 4,652 producers delivered milk to handlers in Louisiana, and their average daily delivery was 289 pounds. By 1961, the number of milk producers had decreased to 3,691, but the average daily delivery had increased to 647 pounds.

The New Orleans Market is the state's largest market, both in terms of number of producers and volume of milk sales to consumers. During an average month in 1952, 2,754 producers delivered milk to handlers in the New Orleans Market. By 1961, the number had declined 24 percent to 2,087 (Table 9).

The total volume of milk received by handlers in the New Orleans Market from producers was 242.1 million pounds in 1952 and 428.5 million pounds in 1961. The average annual delivery of milk per producer was about 88 thousand pounds during 1952. By 1961, the average size producer had increased substantially to about 205 thousand pounds.

TABLE 9.—Number of Milk Producers and Total Producer Receipts, by Markets, Louisiana, 1951-61*

Year	New Orleans**		Northern Louisiana***		Central Louisiana****	
	Number of producers	Total producer receipts	Number of producers	Total producer receipts	Number of producers	Total producer receipts
	Avg. No.	*Million lbs.*	*Avg. No.*	*Million lbs.*	*Avg. No.*	*Million lbs.*
1951	2,738	227.0	566	84.5	1,283	144.4
1952	2,754	242.1	566	89.2	1,332	161.4
1953	2,820	260.4	638	101.7	1,378	178.1
1954	2,764	281.2	656	108.7	1,542	197.9
1955	2,600	294.6	649	120.0	1,587	213.9
1956	2,474	327.2	646	134.1	1,519	228.2
1957	2,258	326.8	657	143.7	1,645	268.6
1958	2,378	339.4	615	142.4	1,313	267.6
1959	2,173	353.7	573	148.8	1,201	256.6
1960	2,163	386.9	572	161.7	1,140	268.7
1961	2,087	428.5	542	167.6	1,062	289.8

*Producer receipts are the volumes of milk delivered to handlers by farmers.

**The New Orleans Market area was expanded December 1, 1957, to include Terrebonne, Lafourche, and St. Charles parishes. Producers shipping milk to handlers regulated by the New Orleans Order as a result of the expansion were reported and shown in the Central Louisiana area prior to the market expansion.

***Prior to August 1958, data for the Shreveport (or Northwest) and Northeast Louisiana Markets were summed for the two areas to approximate the Northern Louisiana Marketing area under Federal Milk Marketing Order Number 96.

****Data as reported for the Central, Southwest, and Southeast Markets were summed to represent the Central Marketing area.

Source: *Louisiana Annual Milk Marketing Report, 1951-1961* (Division of Milk Testing, Louisiana Department of Agriculture and Immigration).

The relative size distribution of producers as measured by their average daily base has also changed, perhaps more strikingly than the changes on the average. The size categories were defined by 100-pound intervals as shown in Figure 4.

In 1957, the largest number of producers in the New Orleans Market was in the size range from 201 to 300 pounds daily base and the smallest number was in the size range of 1,101 to 1,200 pounds daily base (Figure 4). By 1962, the largest number of producers with a base was of the size 301 to 400 pounds per day and the smallest number was in the size category ranging from 1,301 to 1,400 pounds. The change in the distribution of producers from 1957 to 1962 shows that the number of producers in the size ranges of 400 pounds and less decreased while the number in the larger size ranges increased, relatively. This shift is also emphasized by the fact that there were 178 producers with a daily base of 100 pounds or less in 1957 and only 39 in 1962. While there were only 25 producers with a daily base of over 1,400 pounds in 1957, the number increased to 88 by 1962.

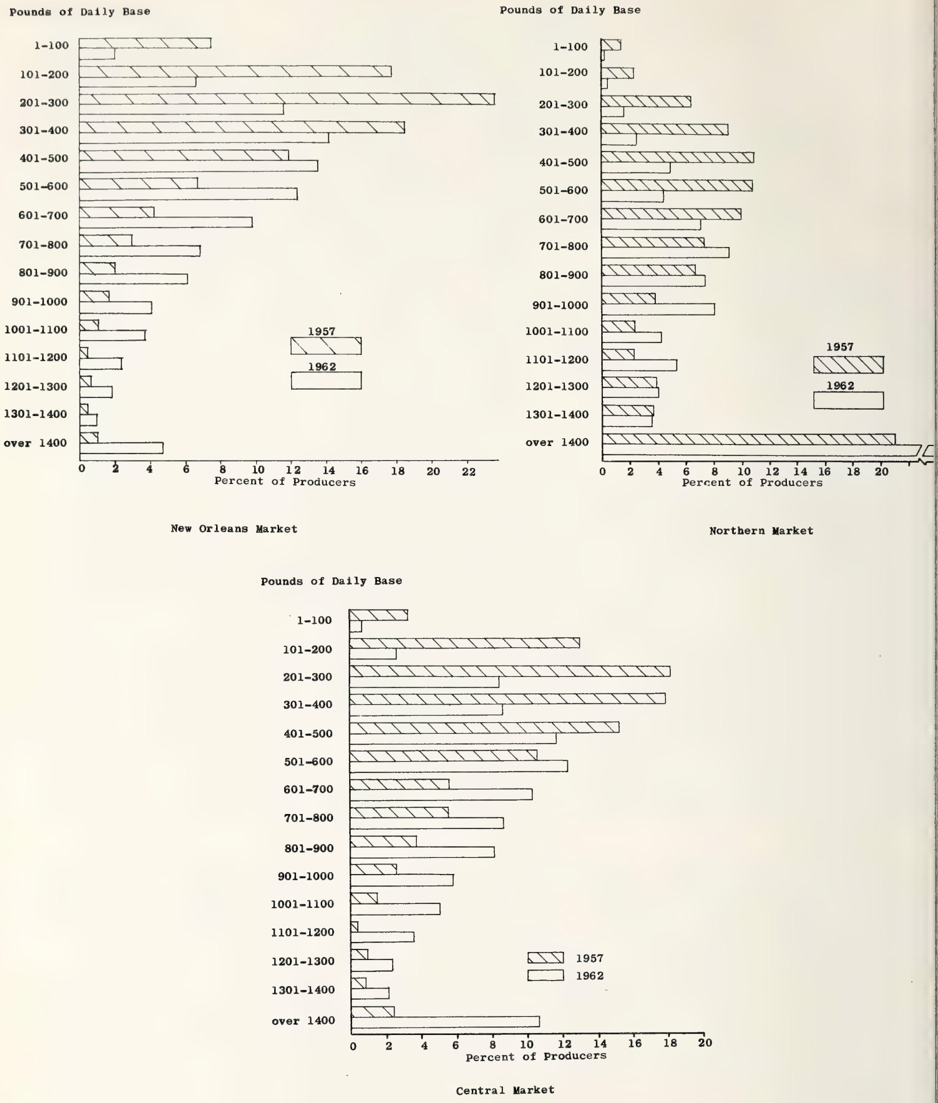

FIGURE 4.—Size Distribution of Milk Producers, Louisiana Markets, Base-operating Periods 1957 and 1962. (Source: Appendix Tables 6 - 8.)

Similar changes occurred in the Northern and Central Markets. (See Table 9 and Figure 4.)

Generally, the number of producers decreased and their average size increased between 1957 and 1962. The number of smaller-sized producers decreased and, conversely, the number of producers in the larger size categories increased, relatively, between 1957 and 1962 for each market.

Changes in Size of Louisiana Milk Producers

Movements of Firms Among Size Categories

The growth pattern of each milk producing firm, in terms of its movements among specified size categories between 1957 and 1962, was observed and analyzed.[57] The individual producer's established daily base was used to represent producer size. Unequal size categories were defined in order to reflect observed ranges of operations by existing producers (Table 10).

TABLE 10.—Ranges of (Unequal) Size Categories Used in the Analysis of Growth Patterns of Milk Producers

Size category	Category limits
	Pounds of daily base
S_a	0
S_b	1-100
S_c	101-300
S_d	301-700
S_e	701-1,500
S_f	> 1,500

The category of no production (S_a) was included to permit producers to leave and enter milk production for the market. Stated another way, the category S_a provides a "reservoir of firms" for potential entrants into the system. This reservoir was defined as the total number of farms in the supply area, less the number of commercial milk producers in the area. The first number in the last column of Table 11, marked by an asterisk, represents this potential for each market respectively. The numbers in the last column of Table 11 represent the number of producers in each size category in 1957. The bottom row for each market shows the number per size category in 1962.

Movements of producers from one category to another which resulted from their decisions to increase or decrease the output of milk between 1957 and 1962 are shown in Table 11. For example, the data for the New Orleans Market show there were 1,016 producers in size category S_c in 1957. By 1962 over 60 percent, or 625, of these producers had moved out of production and only 224 increased their production beyond 300 pounds per day.

An indication of the "turnover" of producers is shown in Table 11. While there were 2,451 producers with a base for the New Orleans Market in 1957, 1,364 of those producers did not have a base for that market in 1962. Thus, 56 percent of the producers holding a base to produce and sell milk to New Orleans handlers in 1957 had gone out of business or entered another market by 1962. There were 822 entrants, or producers, on the market in 1962 that were not on the market in 1957. Of the 1,909 producers with a base for the New Orleans Market in 1962, only 1,087 of these were the same producers who had a base in 1957. More importantly, only 985 of these producers held a base for each year between 1957 and 1962.

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[57] Note that this time period is slightly different from the 1956-62 period used in the analysis of milk handlers.

The same general relation existed with the other two markets (Table 11). However, the "dropout" rate was lower in the Northern Market, where only 39 percent of the producers in 1957 had gone out of business or entered another market by 1962.

TABLE 11.—Growth Patterns of Milk Producers, Louisiana Markets, 1957-62

Size category in 1957	Size category in 1962						Number of producers in 1957
	S_a	S_b	S_c	S_d	S_e	S_f	
NEW ORLEANS MARKET							
S_a	18,426	23	170	390	210	29	19,248*
S_b	162	2	3	9	2	—	178
S_c	625	11	129	201	22	1	1,016
S_d	477	3	38	325	161	7	1,011
S_e	67	—	2	25	108	26	228
S_f	6	—	—	1	2	9	18
Number of producers in 1962	19,790	39	342	951	505	72	21,699
Producers in 1957 = 2,451; in 1962 = 1,909; Dropouts = 1,364; Entrants = 822							
NORTHERN LOUISIANA MARKET							
S_a	26,351	1	10	50	59	12	26,483*
S_b	6	—	1	2	—	—	9
S_c	79	—	25	31	10	1	146
S_d	110	1	7	81	99	5	303
S_e	35	—	2	8	50	25	120
S_f	7	—	—	1	—	24	32
Number of producers in 1962	26,588	2	45	173	218	67	27,093
Producers in 1957 = 610; in 1962 = 505; Dropouts = 237; Entrants = 132							
CENTRAL LOUISIANA MARKET**							
S_a	41,046	2	35	149	114	23	41,369*
S_b	28	1	3	2	—	—	34
S_c	226	1	31	49	11	—	318
S_d	258	1	14	120	101	7	501
S_e	60	—	1	5	63	21	150
S_f	9	—	—	—	4	8	21
Number of producers in 1962	41,627	5	84	325	293	59	42,393
Producers in 1957 = 1,024; in 1962 = 766; Dropouts = 581; Entrants = 323							

(Continued)

TABLE 11.—(Continued)

Size category in 1957	Size category in 1962						Number of producers in 1957
	S_a	S_b	S_c	S_d	S_e	S_f	
	THREE MARKETS COMBINED						
S_a	85,823	26	215	589	383	64	87,100*
S_b	196	3	7	13	2	—	221
S_c	957	12	185	281	43	2	1,480
S_d	845	5	59	526	361	19	1,815
S_e	162	—	5	38	221	72	498
S_f	22	—	—	2	6	41	71
Number of producers in 1962	88,005	46	471	1,449	1,016	198	91,185

Producers in 1957 = 4,085; in 1962 = 3,180; Dropouts = 2,182; Entrants = 1,277

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*This number represents potential entrants in 1957. The total number of farms reported in the 1959 census of agriculture for the area serving the markets, minus the number of producers, was used to represent this potential. Where producers from one parish were shipping to more than one market, the potential producers were allocated among the markets according to the proportion of producers shipping to the respective markets during the base-forming period of 1958.

**Data were incomplete for a small number of producers for the Central Market and were not included in these observations.

Source: Offices of the Milk Marketing Administrators, New Orleans, Shreveport, and Baton Rouge, Louisiana.

A Chi-square test was employed to test the hypothesis of independence of the producers' production in time period t+1 on period t for each market. The test statistic computed for each market with 25 degrees of freedom was: New Orleans, 1,633.7; Northern Louisiana, 408.1; and Central Louisiana, 602.3. The theoretical Chi-square value with 25 degrees of freedom is 44.3 at the .01 level. Since the statistic computed exceeded this theoretical value, the hypothesis was rejected. This result increases confidence in the validity of the assumption that "the probability of moving from one category to another is a function only of the two categories involved."

Transition Probabilities for Milk Producers

Transition probabilities were calculated, as presented in Table 12, from the data in Table 11 which describes the growth pattern of producers. The number in the respective cells of the transition matrices states the probability of a producer's moving from each of the size categories indicated on the left side of the table to the size categories respectively indicated across the top. For example, the probability that a Northern Louisiana producer in category S_c in a given year will be in the same category five years later is .171233. The probability of moving to S_a (no production) is .541096, and the probability of increasing in size to S_d is .212329, to S_e is .068493, and to S_f is .006849. The

TABLE 12.—Transition Probability Matrix of Milk Producers, Louisiana Markets, 1957-1962

	S_a	S_b	S_c	S_d	S_e	S_f
			NEW ORLEANS MARKET			
S_a	.957294	.001195	.008832	.020262	.010910	.001507
S_b	.910112	.011236	.016854	.050562	.011236	—
S_c	.641732	.010827	.126968	.197835	.021654	.000984
S_d	.471810	.002967	.037587	.321464	.159248	.006924
S_e	.293860	—	.008772	.109649	.473684	.114035
S_f	.333333	—	—	.055556	.111111	.500000
			NORTHERN LOUISIANA MARKET			
S_a	.995016	.000038	.000377	.001888	.002228	.000453
S_b	.666667	—	.111111	.222222	—	—
S_c	.541096	—	.171233	.212329	.068493	.006849
S_d	.363036	.003300	.023102	.267327	.326733	.016502
S_e	.291666	—	.016667	.066667	.416667	.208333
S_f	.218750	—	—	.031250	—	.750000
			CENTRAL LOUISIANA MARKET			
S_a	.992192	.000048	.000846	.003602	.002756	.000556
S_b	.823529	.029412	.088235	.058824	—	—
S_c	.710692	.003145	.097484	.154088	.034591	—
S_d	.514970	.001996	.027944	.239521	.201597	.013972
S_e	.400000	—	.006667	.033333	.420000	.140000
S_f	.428572	—	—	—	.190476	.380952
			THREE MARKETS COMBINED			
S_a	.985339	.000299	.002468	.006762	.004397	.000735
S_b	.886878	.013575	.031674	.058823	.009050	—
S_c	.646622	.008108	.125000	.189865	.029054	.001351
S_d	.465565	.002755	.032507	.289807	.198898	.010468
S_e	.325301	—	.010040	.076305	.443775	.144579
S_f	.309859	—	—	.028169	.084507	.577465

Blank cells represent zero coefficients.

chance of a producer in S_c going out of business in five years is greater than his chance of remaining in business. The same type of observations can be made from Table 12 for producers in each category and for each market.

The chance of producers in the two smallest active categories going out of business within five years is greater than 50 percent in both the New Orleans and Northern Markets. The probability is greater than 50 percent that producers in the three smallest size groups in all markets combined will go out of business in five years or less. For the two largest size categories, the greatest probability is for firms to remain in the same size category.

In general, the probability of going out of production decreases as producers increase in size. The category with the smallest probability of going out of business is S_e for the New Orleans and Central Louisiana producers and S_f for the producers in the Northern Market. The data in Table 12 suggest that producers entering the New Orleans or Central Markets are most likely to enter at the size range of S_d (a daily base of from 301 to 700 pounds). These computed transition probabilities were based on a five-year time period, 1957-1962. Any producer in the markets in 1962 but not in the markets in 1957 could have entered at any time between 1957 and 1962. These probabilities may be interpreted to mean that producers are most likely to enter with an output in the size range of S_d or to grow into category S_d within four years after entry. The probability of similar action by producers is slightly greater for entering the Northern Market in S_e. Also, in all three markets there was a greater tendency for small producers remaining in business to increase in size than to remain in the same size category or to decrease in size.

The null hypothesis of no difference in the transition probabilities between markets was tested by the likelihood ratio test as presented by Padberg and Anderson.[58] The calculated value was 1,267.7. Since this value was considerably greater than the Chi-square value of 79.1 required for significance at the .05 level with 60 degrees of freedom, the hypothesis of no difference was not accepted. Thus, the test result shows a significant difference between markets in the forces generating changes in the size distribution of milk producing firms.

Data on established daily base were available each year 1957 through 1962 for milk producers in both the Northern and Central Markets. From this data, transition probabilities were computed using one-year time intervals and *equal* size category ranges of 100 pounds daily base. Because of a lack of data, such calculations were not made for the New Orleans Market.

The transition patterns generally were about the same for the one-year time periods as for the five-year time period, except the probability of going out of business in one year was considerably less than in a five-year period.

Louisiana's base plan of allocating producer milk among class uses provides an economic incentive for each producer to increase milk production during each base-forming period. If a milk producing firm increases production at a greater rate than the market average, it obtains a greater share of Class I sales during the base-operating period. The results of this analysis suggest that milk producers reacted logically to this economic incentive. However, the attempt of a producer to gain a larger share of Class I sales is of no avail unless he can increase his production relatively more than the average producer.

Distribution of Milk Producers

An equilibrium size distribution of producers was computed to study

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[58] Padberg, *op. cit.*, p. 197; and T. W. Anderson, *op. cit.*, p. 49.

TABLE 13.—Percentage of Milk Producers in Each Size Category by Markets, 1957, 1962, and Estimates for 1972 and Equilibrium

Base operating period	Size categories					
	S_a	S_b	S_c	S_d	S_e	S_f
	Percent					
	NEW ORLEANS MARKET					
1957	—	07.26	41.46	41.25	09.30	00.73
1962	—	02.04	17.92	49.82	26.45	03.77
1972	—	01.52	12.84	41.80	34.83	09.01
Equilibrium	—	01.44	12.03	39.61	35.33	11.59
	NORTHERN LOUISIANA MARKET					
1957	—	01.48	23.93	49.67	19.67	05.25
1962	—	00.40	08.91	34.25	43.17	13.27
1972	—	00.22	04.58	23.14	41.27	30.79
Equilibrium	—	00.29	03.94	20.96	34.28	40.53
	CENTRAL LOUISIANA MARKET					
1957	—	03.29	31.07	48.86	14.64	02.14
1962	—	00.67	10.97	42.54	38.21	07.61
1972	—	00.40	06.77	31.48	45.68	15.67
Equilibrium	—	00.38	06.91	31.55	44.95	16.21
	THREE MARKETS COMBINED					
1957	—	05.22	35.80	44.79	12.40	01.79
1962	—	01.39	14.51	45.35	32.44	06.31
1972	—	00.86	10.02	35.81	38.59	14.72
Equilibrium	—	00.81	09.49	33.63	37.22	18.85

the inherent tendencies in the observed growth patterns of milk producing firms (Table 13). The distribution of firms among size categories as observed in 1957 and 1962 and the projected distribution for 1972 are also shown in Table 13. The category of no production, S_a, although employed in most previous phases of the analysis, was omitted because it was not relevant in this analysis. The distribution of producers in absolute numbers per size category for the same time periods is presented in Table 14.

There was a tendency for the percentage of producers in the smaller categories to decrease, relatively (Table 13). For example, the percent of total producers in category S_c decreased from 41 in 1957 to 12 when in equilibrium in the New Orleans Market; from 24 in 1957 to 4 when in equilibrium in the Northern Market; and from 31 in 1957 to 7 when in equilibrium in the Central Market. The proportion of producers in size category S_f increased from 1 percent in 1957 to 12 percent in equilibrium for the New Orleans Market; from 5 percent to 41 percent for the Northern Market; and from 2 percent to 16 percent for the Central Market.

If the observed tendencies persist, the distribution of producers in equilibrium would be such that the largest number would be in the

TABLE 14.—Number of Milk Producers per Size Category, by Markets, Louisiana, 1957, 1962, and Estimates for 1972 and Equilibrium

Base operating period	Size categories						Total
	S_a	S_b	S_c	S_d	S_e	S_f	
				Number			
		NEW ORLEANS MARKET					
1957	—	178	1,016	1,011	228	18	2,451
1962	—	39	342	951	505	72	1,909
1972	—	29	245	798	665	172	1,909
Equilibrium	—	29	241	794	708	232	2,004
		NORTHERN LOUISIANA MARKET					
1957	—	9	146	303	120	32	610
1962	—	2	45	173	218	67	505
1972	—	1	21	106	189	141	458
Equilibrium	—	1	18	97	158	187	461
		CENTRAL LOUISIANA MARKET					
1957*	—	46	435	684	205	30	1,400
1962*	—	7	114	442	397	79	1,039
1972	—	3	51	237	344	118	753
Equilibrium	—	3	49	223	317	114	706
		THREE MARKETS COMBINED					
1957	—	233	1,597	1,998	553	80	4,461
1962	—	48	501	1,566	1,120	218	3,453
1972	—	27	313	1,119	1,206	460	3,125
Equilibrium**	—	26	303	1,075	1,190	603	3,197

*Data were not available for a small number of individual producers. The number per category was estimated by multiplying the percent in each category (of the data available on individual producers) times the total number of producers reported for the market in January adjusted to correspond to the current market area.

**The estimates for each market, including the three markets combined, were developed from four separate transition probability matrices. Because of this procedure, the number of firms for the state (three markets combined) distribution does not equal the sum of the firms estimated in individual markets.

middle-size category, S_d, in the New Orleans Market, in category S_e in the Central Market; and in the largest category, S_f, in the Northern Market. In general, the proportion of producers in size categories S_b and S_c decreased while the proportion in S_e and S_f increased, relatively, throughout the observation and projection periods.

A similar distribution pattern was reflected in the absolute number of producers as shown by the relative distribution. The number of producers holding a base in the New Orleans Market decreased from 2,451 in 1957 to 1,909 in 1962 (Table 14). The same number, 1,909, was estimated for 1972 and increased only slightly to 2,004 for an equilibrium condition. The number of base-holding producers in the Northern Market decreased from 610 in 1957 to 505 in 1962; the estimated number declined further to 458 in 1972, and then increased slightly to 461 in equilibrium.

The greatest estimated decline in number of producers, both relatively and absolutely, occurred in the Central Market. The number of producers decreased 26 percent between 1957 and 1962, or from 1,400 to 1,039. Only 753 were estimated for 1972, and a further decline to 706 was indicated for equilibrium. Although the results indicate a continuous change of producers among size categories, including entry and exit, the total number for equilibrium was approached closely in 1962 in the New Orleans Market and would be almost identical with the number required for equilibrium in the Northern Market by 1972.

Mobility of Milk Producers

The data in the transition matrices (Table 12) suggest that milk producers are rather mobile and indicate the direction of their movements. Data with respect to the mean number of years spent in a specific size category by an average producer are presented in Table 15. The mean lifetime of firms in category S_a was omitted from Table 15 because the number of potential entrants was estimated based on the assumption

TABLE 15.—Mean Lifetime of Milk Producing Firms per Size Category, Louisiana Markets, 1957-62

Size category	Mean lifetime (five years) 1957-62 average	Mean lifetime (five years) Perfectly mobile market	Ratio
	NEW ORLEANS MARKET		
S_b	1.0	1.0	1.0
S_c	1.1	1.1	1.0
S_d	1.5	1.7	0.9
S_e	1.9	1.5	1.3
S_f	2.0	1.1	1.8
	NORTHERN LOUISIANA MARKET		
S_b	1.0	1.0	1.0
S_c	1.2	1.0	1.2
S_d	1.4	1.3	1.1
S_e	1.7	1.5	1.1
S_f	4.0	1.7	2.4
	CENTRAL LOUISIANA MARKET		
S_b	1.0	1.0	1.0
S_c	1.2	1.1	1.1
S_d	1.3	1.5	0.9
S_e	1.7	1.8	0.9
S_f	1.6	1.2	1.3
	THREE MARKETS COMBINED		
S_b	1.0	1.0	1.0
S_c	1.1	1.1	1.0
S_d	1.4	1.5	0.9
S_e	1.8	1.6	1.1
S_f	2.4	1.2	2.0

that all farms are potential dairy farms. This decision to omit S_a was made in spite of the fact that it would be tempting to interpret such an estimate as an indication or measure of the degree of barrier or restriction to entry. Therefore, the mean lifetime for firms in the perfectly mobile market, as shown in Table 15, was computed from the normalized equilibrium vector K so that it would be comparable to the average lifetime of milk producing firms observed operating in the markets.

A ratio was computed showing the relationship between the observed mean lifetime of producers in specific size categories and that expected in corresponding size categories under the concept of a perfectly mobile market. This ratio may be interpreted to mean that as this ratio approaches 1.0, the observed mean lifetime of firms in given size categories approaches that of the perfectly mobile market. The data indicate that producers of each size group were highly mobile and closely approximated a perfectly mobile market. Moreover, there was little difference in the observed mean lifetime of firms between size categories and between markets. There were no noticeable differences in the mobility, whether the computations were based on one-year time periods and equal size category ranges or a five-year time period and unequal size categories.

Also, the market mobility indices for producers, ranging in 1957 from 98.9 for the Northern Market to 118.5 in the Central Market, indicate that milk producers were highly mobile (Table 16). The projected indices indicate a tendency for only a slight decrease in this mobility. An equilibrium condition would reflect a market mobility index of 90.6, 101.1, and 59.4 for the New Orleans, Central, and Northern Markets, respectively. These results suggest that the market structure of milk producers will continue to be highly mobile.

TABLE 16.—Index of Market Mobility of Milk Producers, Louisiana Markets, 1957, 1972, and Equilibrium

Market	Index of mobility		
	1957	1972	Equilibrium
New Orleans	110.2	91.6	90.6
Northern Louisiana	98.9	65.4	59.4
Central Louisiana	118.5	101.0	101.1
Three Markets Combined	105.9	86.5	84.7

Producer Cooperatives

It is generally considered that individual producers—farmers—in the agricultural sector of the economy operate under conditions approaching the economic model of pure competition. The question may be raised as to whether or not the structure of Louisiana milk markets, as reflected by the number and size of milk producers, meets the requirements of the pure competition model.

The previous analysis indicates, among other things, that: (1) there were many milk producers in each market; (2) the size of any individual milk producing firm was not large enough to have a significant effect on the total market supply of milk; (3) the mobility of milk producers was approximately the same as that expected under the concept of a "perfectly mobile market"; (4) the average chance of a producer's remaining in production more than five years was only about 50-50; (5) there appeared to be no significant restriction to entry; and (6) observations in the market indicate that milk sold by producers to handlers is homogeneous. Therefore, it may be concluded that the market structure in which milk producers operate has the characteristics of pure competition. Thus, it appears that individual producers, *per se,* have very little effective bargaining power.

Do producers, with little or no market power, faced with a market in which monopolistic elements are present, have a means of developing countervailing market power? One method utilized, to a limited extent in Louisiana, is producer cooperative associations.

A complete analysis of milk producer cooperatives in Louisiana is beyond the scope of this study. However, cooperative associations should be recognized as a factor in the market structure of the dairy industry in Louisiana. Selected factors which affect the bargaining position of milk producers were examined briefly. This analysis deals with those milk producer bargaining cooperatives officially recognized by administrators of governmental milk marketing orders.

Three milk producer bargaining cooperatives in Louisiana were officially recognized by government agencies in January 1957. The number of cooperatives increased to four by January 1962. This change in number resulted from a merger of two cooperatives and the organization of two new associations. Membership in coöperatives increased from 1,174 in January 1957 to 2,230 in January 1962, or an increase of 91 percent (Table 17). Only 25 percent of all milk producers were cooperative members in January 1957 while 63 percent were members in January 1962. Cooperative members controlled about one-fourth of the total milk supply in January 1957 and 63 percent in January 1962. These data indicate that the bargaining position of milk producers was enhanced through producer organization.

Evidence of increased producer market power was reflected by the fact that in recent years cooperatives negotiated with handlers for premiums over the Class I milk price established by federal order for the New Orleans Market. Producer cooperatives negotiated with milk handlers in the New Orleans Market for a Class I price of $5.90 per

TABLE 17.—Number of Producers and Volume of Milk Marketed by Members of Cooperative Organizations, Louisiana, January, 1957-62

Year	Milk producers: State total	Milk producers: Cooperative members	Milk producers: Cooperative members as percent of total	Producer receipts: State total	Producer receipts: Cooperative members	Producer receipts: Cooperative members as percent of total
January	*Number*		*Percent*	*Thousand Pounds*		*Percent*
1957	4,641	1,174	25.3	64,024	15,719	24.6
1958	4,471	2,193	49.0	59,225	26,715	45.1
1959	4,161	2,293	55.1	62,338	32,056	51.4
1960	3,914	2,071	52.9	66,862	32,775	49.0
1961	3,749	2,401	64.0	74,623	46,856	62.8
1962	3,537	2,230	63.3	70,298	43,989	62.6

Source: *Louisiana Annual Milk Marketing Report* (Division of Milk Testing, Louisiana Department of Agriculture and Immigration, 1957-62); and Records of Milk Producer Cooperatives, Franklinton, Lafayette, Shreveport, and Baton Rouge, Louisiana.

hundred pounds of milk containing 4 percent butterfat for the months of May through September, 1957. During this time, the federal order price ranged from $5.25 to $5.72. Also, a Class I price of $6.00 per hundred pounds of milk at 4 percent butterfat test was negotiated for the months of August 1958 through August 1959, during which time the federal order price averaged $5.72 per month.[59]

Producer cooperatives were instrumental in obtaining a federal milk marketing order for Northern Louisiana in 1955 and state milk marketing orders for all areas of Louisiana in 1960. Also, they have obtained changes in the milk marketing orders which were beneficial to producers.

Structural characteristics as reflected by individual producers indicate that milk production, as such, is characterized by conditions of pure competition. However, producers recognized that organization is essential if they expect to obtain market power. Development of countervailing power in the market through organized cooperative bargaining associations resulted in a market structure in the producer (seller) segment which approaches the model of oligopoly.

SUMMARY

Structural changes have been taking place in the Louisiana dairy industry in terms of number and size distribution of firms, growth patterns, and mobility, as well as survival rates for firms. Analysis of these changes together with an estimate of the structure of the markets in future time periods was the substance of this study. The Markov

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[59] *Louisiana Annual Milk Marketing Report* (Division of Milk Testing, Louisiana Department of Agriculture and Immigration); and *Compilation of Statistical Material for the New Orleans, Louisiana Marketing Area, January 1957 Through August 1961* (New Orleans, Louisiana: Office of the Market Administrator).

Process was employed as the major analytical technique in the study.

Since the effects of business concentration are most significant in local markets, Louisiana was divided into three marketing areas for this analysis in accordance with those of regulatory agencies. These markets were referred to as the New Orleans, Northern, and Central Markets. Both the handler and producer segments were analyzed.

Milk Handler Segment

Relatively few milk handlers operated in each market. The three largest firms accounted for more than half of the total milk sales in each market. The six largest firms accounted for more than 70 percent of sales. Projection analysis indicated further declines in the number of firms in the industry. By 1972, it is expected that 60 firms will serve the industry instead of the 73 currently operating.

Small handlers tended to get smaller or go out of business. The probability of going out of business decreased as firm size increased and was remote for firms whose packaged fluid milk sales were greater than 400 thousand pounds per month. Firms remaining in the markets tended to increase in size and concentrate in the larger size categories. For example, while one-third of the firms in the Northern Market each sold less than 101 thousand pounds of fluid milk per month in 1956, it was estimated that only 8 percent of the firms would be in that category by 1972 and none would be that small in equilibrium. During 1956, one-fifth of the firms operating in that market had sales volume of from 751 thousand to three million pounds per month. Thirty-eight percent of the projected firms in the Northern Market would be in that size group by 1972, and at long-run equilibrium, two-thirds of the firms would have sales in that range.

Sixty-three percent of the firms estimated to be operating in Louisiana in 1972 would be in the largest three categories. In absolute terms the largest number of milk handlers in any one size category would be 17 in S_5, a size range from 751 thousand to three million pounds of packaged fluid milk sales per month. Thirty-eight firms would be in size categories larger than S_3, or would have fluid milk sales exceeding 400 thousand pounds per month. Only eight firms would be in S_1, less than 100 thousand pounds per month.

Milk handlers in Louisiana were rather immobile. Handlers were only about 16 percent as mobile as firms would be in the concept of a "perfectly mobile market." Estimates of firm mobility index declined to 13 in 1972 and 9 in equilibrium.

The analysis indicates the handler segment of the markets will become more rigid as a result of a decrease in the number of firms and the gravitation of the remaining firms to the larger, less mobile, sizes.

Milk Producer Segment

In contrast to the handler segment, the number of milk producers in each market was relatively large and the production of any single producer was insufficient to significantly affect the total market supply. There was a tendency for the number of smaller producers to decrease and for the number of larger producers to increase, relatively.

There was a rapid turnover of producers in each market. For example, 56 percent of the 2,451 producers in the New Orleans Market in 1957 were not operating by 1962. Between 1957 and 1962 there were only 985 producers that remained in continuous production for the New Orleans Market. During that period 1,364 firms with a base in 1957 quit production and 822 new firms gained bases for that market.

On the average, there was only about a 50-50 chance of a producer remaining in production as long as five years. The probability of going out of production decreased as producers increased in size. Producers with an average daily base ranging from 1,101 to 1,200 pounds were less likely to go out of production in one year than firms of any other size. Irrespective of the firm's size, if it remained in business it was more likely to increase than to decrease in size.

If observed tendencies persist, the equilibrium number of producers would be approximated by 1972. The largest number of producers would have milk production ranging from 301 to 700, 701 to 1,500, and over 1,500 pounds per day for the New Orleans, Central, and Northern Markets, respectively.

The index of firm mobility in the markets indicates that producers are highly mobile, approaching the "perfectly mobile market" concept. The index of market mobility estimated for equilibrium showed some decline. In equilibrium conditions, the market mobility index was calculated to be 59 for the Northern Market and over 90 for both the Central and New Orleans Markets.

Milk producers, recognizing that organization is essential for them to obtain market power, have developed a countervailing power in the market through cooperative bargaining associations. This countervailing power was evidenced by the fact that producer cooperatives negotiated with handlers for premiums over the Class I milk price established by federal order for the New Orleans Market; they were instrumental in obtaining a federal milk marketing order for Northern Louisiana and state milk marketing orders for all areas of Louisiana.

The structural relation between milk producers and milk handlers in Louisiana markets seems to fit the models of oligopoly versus oligopsony. Status of oligopoly for milk producing firms was achieved through cooperative bargaining associations.

APPENDIX A
PROCEDURE USED TO OBTAIN DATA

As indicated earlier, data requirements of the Markov Process are stringent; information about the size of individual firms over time is required. In some cases such data are not available because of the lack of records. Also, in many cases data of this nature are considered confidential. Where these data problems exist, they must be overcome before the technique can be used.

The problem of obtaining confidential data may be approached by different methods. One approach to the problem would be to request data from individual firms in terms of size categories by time periods. Firms may be less reluctant to release data relating to their business within ranges than by absolute values. From such data, the researcher could determine the movements by firms among size categories.

Another approach to the problem would be to request data from an alternative source, such as a governmental regulatory agency. Most agencies, however, are not permitted to release confidential information about individual firms. Therefore, it may be necessary for the agency to release the data in a form which does not reveal confidential information. Here again, data could be requested in terms of size categories. Such data could also be coded and thus not reveal the identity of any given firm. Movements of firms among size categories could be determined by the researcher from data in this form.

Another approach to the problem would be to request the agency to provide the data in terms of observed movements of firms among size categories, or in terms of transition probabilities. Data in such form, plus the number of firms per size category during the initial time period, satisfy the requirements of the model. Also, under such a procedure it is impossible to determine information about any individual firm. In some cases, it may be necessary to specify that there must be at least three firms in each size category before the agency can release the data. This procedure requires that the agency observe and record the movements of each individual firm among size categories.

For this study, data on movements of milk handlers among size categories were obtained from the Market Administrators in the form of a matrix. The elements of the matrix, A_{ij} (the subscript i refers to the row, and j refers to the column), represent the total number of firms that moved from S_i to S_j during all time intervals, where S_i represents the size category in a given time period, and S_j represents the size category in the following time period. Data in this form are consistent with the needs for analysis with the Markov Process and consistent with rules for releasing market data.

A procedure for determining the movements of each individual firm among size categories was explained to the administrators by the following hypothetical example: Assume that there are eight size categories (Appendix Table 1-A). The volume of milk sales for six time periods was assumed for each firm; the volume of each firm was assigned to a size category for each time period (Appendix Table 1-B). A matrix was formed to record movements by firms among size categories. This was done by indicating size categories for a given time period in a column on the left side of a table and indicating size categories for the following time period in a row across the top (Appendix Table 1-C).

APPENDIX TABLE 1-A.—Hypothetical Data for Illustrating Movements of Firms Among Size Categories

Size category	Volume of sales
	Million pounds per time period
1	0
2	1 or less
3	1.1 to 10
4	10.1 to 20
5	20.1 to 30
6	30.1 to 40
7	40.1 to 50
8	50.1 or greater

Movements of each hypothetical firm among size categories were recorded in Appendix Table 1-C from the data in Appendix Table 1-B. For example, firm N was in category 3 in 1955 and category 2 in 1956. This change constitutes one movement, or one observation, for element A_{32} in Appendix Table 1-C. Firm N was in category 4 in 1957, which gives one observation for element A_{24}. In 1958, firm N was in category 1. This movement provides an observation for element A_{41}, and so on, for each individual firm. Transition probabilities can be computed from data in this form.

APPENDIX TABLE 1-B.—Hypothetical Data for Illustrating Movements of Firms Among Size Categories

Firm	1955		1956		1957		1958		1959		1960	
	Category	Volume	Category	Volume	Category	Volume	Category	Volume	Category	Volume	Category	Volume
		Mil. lbs.		*Mil. lbs.*		*Mil. lbs.*		*Mil. lbs.*		*Mil. lbs.*		*Mil. lbs.*
A	2	.5	2	.8	3	1.1	2	.7	2	.9	3	1.5
B	3	5.4	3	8.7	3	6.3	4	10.3	4	11.5	3	9.4
C	8	50.7	7	48.6	8	52.3	8	55.0	7	45.0	7	48.0
D	7	45.0	8	51.0	8	52.0	7	47.0	6	39.0	6	38.0
E	2	.3	2	.8	2	1.0	3	6.0	3	10.0	4	15.0
F	2	.2	2	.7	2	.5	1	0.0	1	0.0	1	0.0
G	3	10.0	4	15.0	4	18.0	5	25.0	5	29.0	5	30.0
H	7	40.5	6	38.0	6	39.0	7	42.0	7	45.0	7	43.0
I	3	9.0	3	8.0	3	10.0	4	12.0	4	15.0	5	20.6
J	3	9.0	4	15.0	4	19.0	5	30.0	6	34.0	5	28.0
K	5	25.0	5	28.0	4	18.0	4	19.0	5	25.0	5	30.0
L	2	.4	2	.5	2	.6	2	.9	3	10.0	4	20.0
M	4	12.0	4	18.0	5	22.0	7	41.0	7	43.0	6	39.0
N	3	10.0	2	.9	4	13.0	1	0.0	1	0.0	1	0.0
O	1	0.0	1	0.0	3	4.0	3	6.0	3	5.0	2	.9
P	4	20.0	5	24.0	5	27.0	7	42.0	7	44.0	6	40.0
Q	7	49.0	8	54.0	8	56.0	8	58.0	8	52.0	8	59.0
R	2	.8	3	9.0	3	10.0	4	18.0	5	24.0	5	30.0
S	2	.9	2	.8	2	1.0	3	4.0	3	9.0	4	11.0
T	3	8.0	4	12.0	4	18.0	4	20.0	5	22.0	4	17.0
U	6	31.0	5	30.0	5	25.0	4	19.0	4	18.0	1	0.0
V	3	2.0	3	4.0	2	.9	2	.8	2	.8	3	2.0
W	5	30.0	6	37.0	5	28.0	5	25.0	6	32.0	8	52.0
X	4	20.0	1	0.0	1	0.0	1	0.0	1	0.0	1	0.0
Y	5	30.0	7	48.0	8	52.0	8	53.0	8	54.0	8	52.0
Z	3	7.0	3	5.0	1	0.0	1	0.0	1	0.0	1	0.0

APPENDIX TABLE 1-C.—Hypothetical Data for Illustrating Movements of Firms Among Size Categories

Size category in time period	Size category in following time period							
	1	2	3	4	5	6	7	8
1	11111 11111 11		1					
2	1	11111 11111 111	11111 11	1				
3	1	1111	11111 11111 1	11111 1111				
4	111		1	11111 1111	11111 111			
5				111	11111 111	111	111	
6					111	11	1	1
7						1111	11111	1111
8							111	11111 1111

APPENDIX B

A TECHNIQUE FOR OBTAINING THE EQUILIBRIUM DISTRIBUTION

It was shown earlier that the equilibrium distribution of firms in a market can be derived by raising the transition matrix to an infinite power, or by the solution of simultaneous equations. Each of these methods results in a unique vector which shows the equilibrium distribution.

A procedure of setting up the system of simultaneous equations to solve for the equilibrium vector, K, may not be readily apparent to one who is not familiar with matrix algebra. Therefore, such a procedure is presented in this Appendix. In equilibrium,

(1) $KP = K$.

In general, this equation may be expressed as

$$(2)\quad [k_1\ k_2 \ldots k_{r-1}\ k_r]\begin{bmatrix} p_{11} & p_{12} & \cdots p_{1,r-1} & p_{1r} \\ p_{21} & p_{22} & \cdots p_{2,r-1} & p_{2r} \\ \cdots & \cdots & \cdots & \cdots \\ p_{r-1,1} & p_{r-1,2} & \cdots p_{r-1,r-1} & p_{r-1,r} \\ p_{r1} & p_{r2} & \cdots p_{r,r-1} & p_{rr} \end{bmatrix} = (k_1\ k_2 \ldots k_{r-1}\ k_r).$$

If each matrix of (2) is transposed, the order of multiplication is changed and the equation would appear as

$$(3)\quad \begin{bmatrix} p_{11} & p_{21} & \cdots p_{r-1,1} & p_{r1} \\ p_{12} & p_{22} & \cdots p_{r-1,2} & p_{r2} \\ \cdots & \cdots & \cdots & \cdots \\ p_{1,r-1} & p_{2,r-1} & \cdots p_{r-1,r-1} & p_{r,r-1} \\ p_{1r} & p_{2r} & \cdots p_{r-1,r} & p_{rr} \end{bmatrix}\begin{bmatrix} k_1 \\ k_2 \\ \cdots \\ k_{r-1} \\ k_r \end{bmatrix} = \begin{bmatrix} k_1 \\ k_2 \\ \cdots \\ k_{r-1} \\ k_r \end{bmatrix}$$

This system of equations (3) is equal to

$$(4)\quad \begin{array}{llllll} p_{11}k_1 & + p_{21}k_2 & + \cdots + p_{r-1,1}k_{r-1} & + p_{r1}k_r & = k_1 \\ p_{12}k_1 & + p_{22}k_2 & + \cdots + p_{r-1,2}k_{r-1} & + p_{r2}k_r & = k_2 \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ p_{1,r-1}k_1 & + p_{2,r-1}k_2 & + \cdots + p_{r-1,r-1}k_{r-1} & + p_{r,r-1}k_r & = k_{r-1} \\ p_{1r}k_1 & + p_{2r}k_2 & + \cdots + p_{r-1,r}k_{r-1} & + p_{rr}k_r & = k_r \end{array}$$

which is a system of r equations and r unknowns. However, since

(5) $k_1 + k_2 + \ldots + k_{r-1} + k_r = 1$,

only r-1 of the equations in the system (4) are linearly independent. This same equation $(k_1 + k_2 + \cdots + k_{r-1} + k_r = 1)$ provides an equation that can be used to replace any one of the system.

Let the last equation in the system (4) be replaced by equation (5). This replacement provides a system of r linearly independent equations and r unknowns that would appear as

$$
(6)\quad
\begin{array}{lllllllll}
p_{11}k_1 & + & p_{21}k_2 & + \cdots + & p_{r-1,1}k_{r-1} & + & p_{r1}k_r & = & k_1 \\
p_{12}k_1 & + & p_{22}k_2 & + \cdots + & p_{r-1,2}k_{r-1} & + & p_{r2}k_r & = & k_2 \\
\multicolumn{9}{c}{\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots} \\
p_{1,r-1}k_1 & + & p_{2,r-1}k_2 & + \cdots + & p_{r-1,r-1}k_{r-1} & + & p_{r,r-1}k_r & = & k_{r-1} \\
1k_1 & + & 1k_2 & + \cdots + & 1k_{r-1} & + & 1k_r & = & 1
\end{array}
$$

By transferring all of the unknowns (k_1) to the same side of the equation and collecting like terms, the system of equations would appear as

$$
(7)\quad
\begin{array}{lllllllll}
p_{11}k_1\text{-}k_1 & + & p_{21}k_2 & + \cdots + & p_{r-1,1}k_{r-1} & + & p_{r1}k_r & = & 0 \\
p_{12}k_1 & + & p_{22}k_2\text{-}k_2 & + \cdots + & p_{r-1,2}k_{r-1} & + & p_{r2}k_r & = & 0 \\
\multicolumn{9}{c}{\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots} \\
p_{1,r-1}k_1 & + & p_{2,r-1}k_2 & + \cdots + & p_{r-1,r-1}k_{r-1}\text{-}k_{r-1} & + & p_{r,r-1}k_r & = & 0 \\
1k_1 & + & 1k_2 & + \cdots + & 1k_{r-1} & + & 1k_r & = & 1
\end{array}
$$

Now by factoring like terms, the system of equations would appear as

$$
(8)\quad
\begin{array}{lllllllll}
(p_{11}\text{-}1)k_1 & + & p_{21}k_2 & + \cdots + & p_{r-1,1}k_{r-1} & + & p_{r1}k_r & = & 0 \\
p_{12}k_1 & + & (p_{22}\text{-}1)\,k_2 & + \cdots + & p_{r-1,2}k_{r-1} & + & p_{r2}k_r & = & 0 \\
\multicolumn{9}{c}{\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots} \\
p_{1,r-1}k_1 & + & p_{2,r-1}k_2 & + \cdots + & (p_{r-1,r-1}\text{-}1)k_{r-1} & + & p_{r,r-1}k_r & = & 0 \\
1k_1 & + & 1k_2 & + \cdots + & 1k_{r-1} & + & 1k_r & = & 1
\end{array}
$$

and the system of r linearly independent equations and r unknowns is ready for solution.

A technique of obtaining the unique row vector K, as shown by Padberg,[60] may be presented as follows: Let P' be the transpose of the matrix P (the matrix of transition probabilities). Let P* be P'-I, where I is an identity matrix. Replace the i row of P* with a row containing all 1's and call it P**. Now let a column vector with zero in all elements except the i element which is 1 be called v. Then $P^{**-1}\,v = k'$, where P^{**-1} is the inverse of P** and K' is the transpose of K. The transpose of K' will be equal to the unique vector K.

These steps are illustrated by using the following hypothetical example:

---

[60] Padberg, *op. cit.,* p. 190.

$$P' = \begin{bmatrix} .5 & .2 & .0 \\ .3 & .6 & .3 \\ .2 & .2 & .7 \end{bmatrix} ,$$

$$P^* = \begin{bmatrix} .5 & .2 & .0 \\ .3 & .6 & .3 \\ .2 & .2 & .7 \end{bmatrix} - \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} -.5 & .2 & .0 \\ .3 & -.4 & .3 \\ .2 & .2 & -.3 \end{bmatrix}$$

$$P^{**} = \begin{bmatrix} -.5 & .2 & .0 \\ .3 & -.4 & .3 \\ 1.0 & 1.0 & 1.0 \end{bmatrix}$$

$$P^{**-1} = \begin{bmatrix} \frac{-.7}{.35} & \frac{-.2}{.35} & \frac{.06}{.35} \\ \frac{0}{.35} & \frac{-.5}{.35} & \frac{.15}{.35} \\ \frac{.7}{.35} & \frac{.7}{.35} & \frac{.14}{.35} \end{bmatrix} = \begin{bmatrix} -2.00000 & -.57143 & .17143 \\ 0.00000 & -1.42857 & .42857 \\ 2.00000 & 2.00000 & .40000 \end{bmatrix} ,$$

$$V = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} ,$$

$$K' = P^{**-1}v = \begin{bmatrix} -2.00000 & -.57143 & .17143 \\ 0.00000 & -1.42857 & .42857 \\ 2.00000 & 2.00000 & .40000 \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$

$$= \begin{bmatrix} .17143 \\ .42857 \\ .40000 \end{bmatrix} , \text{ and } K = [\ .17143 \quad .42857 \quad .40000].$$

APPENDIX TABLE 2.—Size Distribution of Fluid Milk Firms as Reflected by Packaged Fluid Milk Sales, New Orleans, Louisiana, Market, January 1958 and January 1962

Groups of threes in descending order*	Packaged fluid milk sales	Cumulative volume	Cumulative percent of sales	Cumulative percent of firms
Group	*Thousand Pounds*		*Percent*	
		JANUARY 1958		
1	12,403	12,403	58.6	10.3
2	4,177	16,580	78.3	20.7
3	1,511	18,091	85.5	31.0
4	1,167	19,258	91.0	41.4
5	766	20,024	94.6	51.7
6	495	20,519	96.9	62.1
7	273	20,792	98.2	72.4
8	207	20,999	99.2	82.8
9**	170	21,169	100.0	100.0
		JANUARY 1962		
1	13,508	13,508	55.7	10.3
2	4,863	18,371	75.7	20.7
3	2,205	20,576	84.8	31.0
4	1,414	21,990	90.7	41.4
5	926	22,916	94.5	51.7
6	666	23,582	97.2	62.1
7	344	23,926	98.6	72.4
8	193	24,119	99.4	82.8
9**	136	24,255	100.0	100.0

*Data were grouped into categories of three firms in order to protect confidentiality of the information.

**Group of the five smallest firms.

Source: Office of the Market Administrator, Federal Order 94, New Orleans, Louisiana.

APPENDIX TABLE 3.—Size Distribution of Fluid Milk Firms, as Reflected by Packaged Fluid Milk Sales, Northern Louisiana Market, January 1956 and January 1962

Groups of threes in descending order*	Packaged fluid milk sales	Cumulative volume	Cumulative percent of sales	Cumulative percent of firms
Group	*Thousand Pounds*		*Percent*	
		JANUARY 1956		
1	7,800	7,800	68.9	20.0
2	2,036	9,836	86.9	40.0
3	849	10,685	94.4	60.0
4	429	11,114	98.2	80.0
5	204	11,318	100.0	100.0
		JANUARY 1962		
1	9,069	9,069	68.2	23.1
2	2,592	11,661	87.7	46.2
3	1,279	12,940	97.3	69.2
4**	354	13,294	100.0	100.0

*Data were grouped into categories of three firms in order to protect confidentiality of the information.

**Group of the four smallest firms.

Source: Office of the Market Administrator, Federal Order 96, Shreveport Louisiana.

APPENDIX TABLE 4.—Size Distribution of Fluid Milk Firms as Reflected by Packaged Fluid Milk Sales, Central Louisiana Market, January 1952, January 1958, and January 1962

Groups of threes in descending order*	Packaged fluid milk sales	Cumulative volume	Cumulative percent of sales	Cumulative percent of firms
Group	*Thousand Pounds*		*Percent*	
JANUARY 1952				
1	5,503	5,503	39.6	7.5
2	2,798	8,301	59.8	15.0
3	1,545	9,846	70.9	22.5
4	971	10,817	77.9	30.0
5	768	11,585	83.5	37.5
6	525	12,110	87.2	45.0
7	388	12,498	90.0	52.5
8	288	12,786	92.1	60.0
9	272	13,058	94.1	67.5
10	249	13,307	95.9	75.0
11	227	13,534	97.5	82.5
12	185	13,719	98.8	90.5
13**	161	13,880	100.0	100.0
JANUARY 1958				
1	11,750	11,750	54.4	9.1
2	3,613	15,363	71.1	18.2
3	1,571	16,934	78.4	27.2
4	1,341	18,275	84.6	36.3
5	947	19,222	89.0	45.4
6	700	19,922	92.2	54.5
7	552	20,474	94.8	63.6
8	413	20,887	96.7	72.7
9	330	21,217	98.3	81.8
10	259	21,476	99.5	90.0
11	117	21,593	100.0	100.0
JANUARY 1962				
1	13,197	13,197	56.9	12.0
2	4,422	17,619	75.9	24.0
3	1,790	19,409	83.7	36.0
4	1,429	20,838	89.8	48.0
5	1,060	21,898	94.4	60.0
6	711	22,609	97.5	72.0
7	402	23,011	99.2	84.0
8**	188	23,199	100.0	100.0

*Data were grouped into categories of three firms in order to protect confidentiality of the information.

**Group of the four smallest firms.

Source: Office of the Administrator, Louisiana Orders 2 and 3, Baton Rouge, Louisiana.

APPENDIX TABLE 5.—Size Distribution of Fluid Milk Firms as Reflected by Packaged Fluid Milk Sales, Three Markets Combined, January 1962

Groups of threes in descending order*	Packaged fluid milk sales	Cumulative volume	Cumulative percent of sales	Cumulative percent of firms
Group	*Thousand Pounds*		*Percent*	
1	25,494	25,494	40.5	4.5
2	8,553	34,047	54.1	8.9
3	5,451	39,498	62.7	13.4
4	4,422	43,920	69.7	17.9
5	3,517	47,437	75.3	22.4
6	3,040	50,477	80.1	26.9
7	1,888	52,365	83.1	31.3
8	1,637	54,002	85.7	35.8
9	1,499	55,501	88.1	40.3
10	1,414	56,915	90.4	44.8
11	1,247	58,162	92.3	49.2
12	1,018	59,180	94.0	53.7
13	903	60,083	95.4	58.2
14	793	60,876	96.6	62.7
15	566	61,442	97.5	67.2
16	371	61,813	98.1	71.6
17	332	62,145	98.7	76.1
18	282	62,427	99.1	80.6
19	204	62,631	99.4	85.1
20	157	62,788	99.7	89.6
21	128	62,916	99.9	94.0
22**	73	62,989	100.0	100.0

*Data were grouped into categories of three firms in order to protect confidentiality of the information.

**Group of the four smallest firms.

Source: Office of the Milk Marketing Administrators, New Orleans, Shreveport and Baton Rouge, Louisiana.

APPENDIX TABLE 6.—Size Distribution of Milk Producers as Reflected by Established Daily Base Pounds, New Orleans, Louisiana Market, Base Operation Period, 1957 and 1962

Size category	Number of producers per size category	Estimated volume of daily base*	Cumulative volume	Cumulative percent of volume	Cumulative percent of producers
Pounds	*Number*	*Pounds*		*Percent*	
		1957			
Over 1400	25	49,408	49,408	5	1
1301-1400	10	13,500	62,908	7	1
1201-1300	14	17,500	80,408	9	2
1101-1200	9	10,350	90,758	10	2
1001-1100	24	25,200	115,958	13	3
901-1000	40	38,000	153,958	17	5
801- 900	50	42,500	196,458	21	7
701- 800	74	55,500	251,958	27	10
601- 700	104	67,600	319,558	35	14
501- 600	165	90,750	410,308	44	21
401- 500	291	130,950	541,258	58	33
301- 400	451	157,850	699,108	75	51
201- 300	578	144,500	843,608	91	75
101- 200	438	65,700	909,308	98	93
1- 100	178	8,900	918,208	100	100
		1962			
Over 1400	88	164,025	164,025	14	5
1301-1400	17	22,950	186,975	16	6
1201-1300	34	42,500	229,475	20	7
1101-1200	46	52,900	282,375	25	10
1001-1100	70	73,500	355,875	31	13
901-1000	76	72,200	428,075	37	17
801- 900	116	98,600	526,675	46	23
701- 800	130	97,500	624,175	54	30
601- 700	187	121,550	745,725	64	40
501- 600	236	129,800	875,525	75	52
401- 500	257	115,650	991,175	85	66
301- 400	271	94,850	1,086,025	94	80
201- 300	220	55,000	1,141,025	98	92
101- 200	122	18,300	1,159,325	99	98
1- 100	39	1,950	1,161,275	100	100

*Estimated by multiplying the number of producers per size category times the mid-point of the category. For the group "over 1400," the number of producers in that size category was multiplied times the average size of the producers in the category.

Source: Office of the Market Administrator, Federal Order 94, New Orleans, Louisiana.

APPENDIX TABLE 7.—Size Distribution of Milk Producers as Reflected by Established Daily Base Pounds, Northern Louisiana Market, Base Operating Period, 1957 and 1962

Size category	Number of producers per size category	Estimated volume of daily base*	Cumulative volume	Cumulative percent of volume	Cumulative percent of producers
Pounds	*Number*	*Pounds*		*Percent*	
		1957			
Over 1400	39	76,050	76,050	21	6
1301-1400	10	13,500	89,550	25	8
1201-1300	11	13,750	103,300	29	10
1101-1200	7	8,050	111,350	31	11
1001-1100	8	8,400	19,750	33	12
901-1000	14	13,300	133,050	37	15
801- 900	28	23,800	156,850	44	19
701- 800	35	26,250	183,100	51	25
601- 700	55	35,750	218,850	61	34
501- 600	70	38,500	257,350	72	45
401- 500	86	38,700	296,050	82	60
301- 400	92	32,200	328,250	91	75
201- 300	90	22,500	350,750	98	89
101- 200	56	8,400	359,150	99	99
1- 100	9	450	359,600	100	100
		1962			
Over 1400	78	180,180	180,180	38	15
1301-1400	13	17,550	197,730	42	18
1201-1300	15	18,750	216,480	45	21
1101-1200	22	25,300	241,780	51	25
1001-1100	19	19,950	261,730	55	29
901-1000	40	38,000	299,730	63	37
801- 900	41	34,850	334,580	70	45
701- 800	57	42,750	377,330	79	56
601- 700	51	33,150	410,480	86	67
501- 600	38	20,900	431,380	91	74
401- 500	51	22,950	454,330	95	84
301- 400	33	11,550	465,880	98	91
201- 300	31	7,750	473,630	99	97
101- 200	14	2,100	475,730	100	99
1- 100	2	100	475,830	100	100

*Estimated by multiplying the number of producers per size category times the mid-point of the category. For the group "over 1400," the number of producers in that size category was multiplied times the average size of the producers in the category.

Source: Office of the Market Administrator, Federal Order 96, Shreveport, Louisiana.

APPENDIX TABLE 8.—Size Distribution of Milk Producers as Reflected by Established Daily Base Pounds, Central Louisiana Market, Base Operating Period, 1957 and 1962

Size category	Number of producers per size category*	Estimated volume of daily base**	Cumulative volume	Cumulative percent of volume	Cumulative percent of producers
Pounds	*Number*	*Pounds*		*Percent*	
		1957			
Over 1400	34	64,566	64,566	10	2
1301-1400	11	14,850	79,416	12	3
1201-1300	13	16,250	95,666	15	4
1101-1200	6	7,500	103,166	16	5
1001-1100	21	22,050	125,216	19	6
901-1000	35	33,250	158,466	24	9
801- 900	52	44,200	202,666	31	12
701- 800	63	47,250	249,916	38	17
601- 700	77	50,050	299,966	46	22
501- 600	147	80,850	380,816	58	33
401- 500	211	94,950	475,766	73	48
301- 400	249	87,150	562,916	86	66
201- 300	253	63,250	626,166	95	84
101- 200	182	27,300	653,466	99	97
1- 100	46	2,300	655,766	100	100
		1962			
Over 1400	110	210,100	210,100	26	11
1301-1400	22	29,700	239,800	30	13
1201-1300	24	30,000	269,800	33	15
1101-1200	36	41,400	311,200	38	18
1001-1100	52	54,600	365,800	45	23
901-1000	59	56,050	421,850	52	29
801- 900	84	71,400	493,250	61	37
701- 800	89	66,750	560,000	69	46
601- 700	105	68,250	628,250	77	56
501- 600	128	70,400	698,650	86	68
401- 500	121	54,450	753,100	93	80
301- 400	88	30,800	783,900	97	88
201- 300	87	21,750	805,650	99	97
101- 200	27	4,050	809,700	100	99
1- 100	7	350	810,050	100	100

*Data were not available for all individual producers. The number per category was estimated by multiplying the percent in each category, of the data available on individual producers, times the total number of producers reported for the market.

**Estimated by multiplying the number of producers per size category times the mid-point of the category. For the group "over 1400," the number of producers in that size category was multiplied times the average size of the producers in the category.

Source: Office of the Market Administrator, Louisiana Orders 2 and 3, Baton Rouge, Louisiana.

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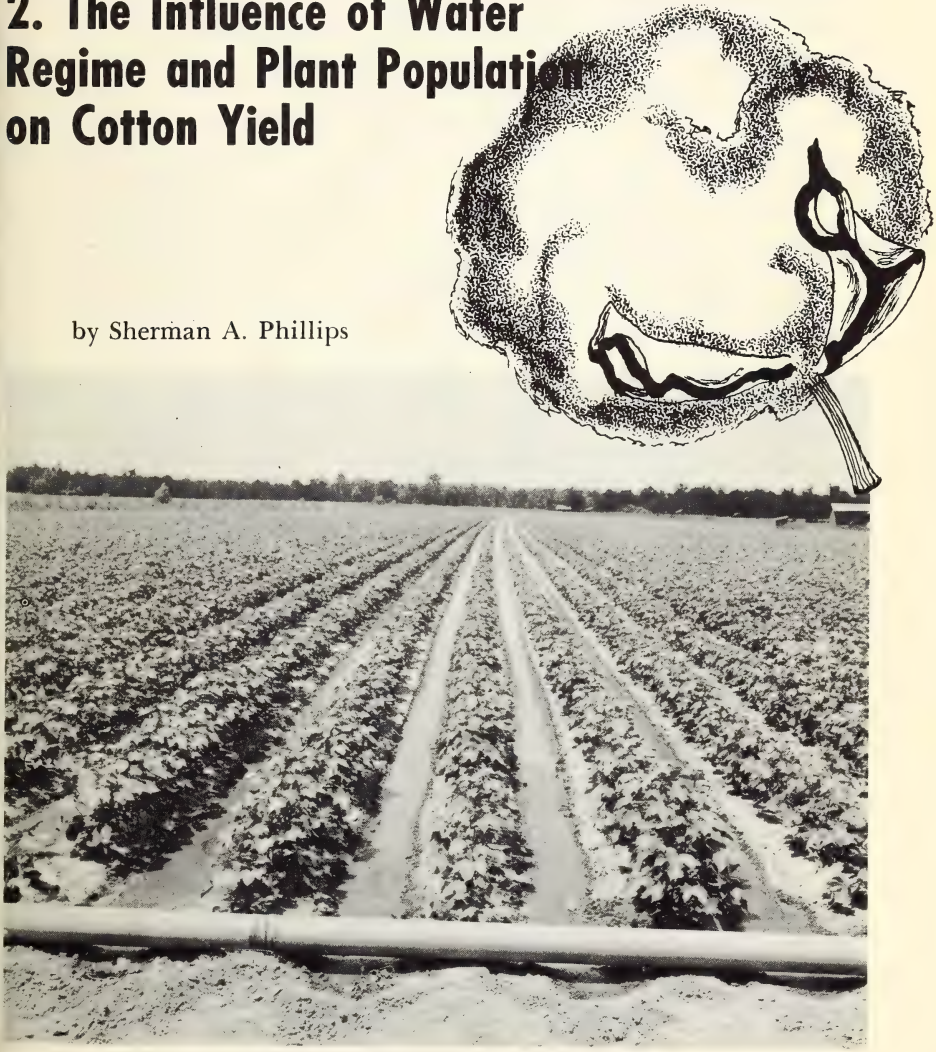
COTTON IRRIGATION STUDIES

1. Effect of Irrigation on Response to Fertilization

2. The Influence of Water Regime and Plant Population on Cotton Yield

by Sherman A. Phillips



Louisiana State University and
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Agricultural Experiment Station
Charles W. Upp, Director

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Cotton Irrigation Studies

1. Effect of Irrigation on Response to Fertilization

2. The Influence of Water Regime and Plant Population on Cotton Yield

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SHERMAN A. PHILLIPS*

Many environmental conditions as well as cultural practices affect the response of cotton to irrigation and fertilization. These include such things as physical and chemical properties of the soil, crop rotation, land forming, fertilizer rates, temperature, cloudiness, humidity, insect control, kind and amount of soil borne diseases, etc. However, soil moisture during the growing season appears to be the *most important factor* governing responses on Mississippi terrace soils. Uneven distribution and in some years inadequate amounts of rainfall during the growing season have caused some farmers to use supplemental irrigation as a means of balancing out unpredictable seasonal variations in natural rainfall.

To help answer questions which arose as the irrigated acreage increased, experiments were set up in 1957 at the Macon Ridge Branch Experiment Station, Winnsboro, Louisiana. Objectives of the experiments were: (1) to determine the yield response to irrigation, (2) to determine the effect of irrigation on the response of cotton to fertilization, (3) to follow moisture patterns and root penetration throughout the growing season on irrigated and non-irrigated cotton, (4) to determine the optimum moisture level for the production of cotton, and (5) to determine the effect of plant population on yield.

Review of Literature

In 1961, Brown *et al.* (2) reported that when approximately 100 pounds of nitrogen was used on Grenada soil the increased yields due to irrigation ranged from 0 to 1,521 pounds per acre, the 6-year average increase being 648 pounds of seed cotton per acre. A nitrogen rate between 80 and 100 pounds per acre was recommended for irrigated and non-irrigated cotton. Irrigation and nitrogen fertilization rates up to 264 pounds did not adversely affect the height of cotton plants nor significantly delay maturity of the crop.

Raney (7) reported more efficient response of cotton to nitrogen under irrigated than non-irrigated conditions. At the 120 pound level of nitrogen application the increased yield was 700 pounds for irrigated and 400 pounds for non-irrigated cotton.

Scarsbrook *et al.* (8) reported that high nitrogen content of the cotton plant was associated with high yields and that nitrogen also increased the efficiency of irrigation water. They also reported interaction of nitrogen and moisture on cotton yields in 1959. Under irrigated conditions in combination with 240 pounds of nitrogen per acre 1,794 pounds of lint cotton was produced.

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*Assistant Professor of Agronomy, Macon Ridge Branch, Northeast Louisiana Experiment Station.

Marshall *et al.* (5) and Phillips (6) reported that cotton yields were increased on Lintonia, Richland and Olivier silt loam soils from the addition of phosphorus and/or potassium fertilizers.

Cowan *et al.* (3) stated that boll rot, boll shedding and lodging are associated with high nitrogen and water and are most pronounced under high plant population. Acala 4-42 and Deltapine Smooth Leaf were found to perform differently under varying amounts of nitrogen and water regimes. Lint yields of Acala 4-42 were highest when plants received only adequate supplies of nitrogen and water. When nitrogen fertility level is adequate for maximum yields, excessive irrigation can produce such rank cotton with large amounts of boll rot that resulting yields are lower than those obtained under nitrogen deficiency conditions. Deltapine Smooth Leaf variety also grew more rank when given extra amounts of water and nitrogen but boll rot was not severe and yields were not depressed.

Amemiya *et al.* (1) found that the peak period of soil water depletion occurred at early bloom. High soil water extended this period and increased the rate and amount of water depleted. Cotton roots may extract water below their primary root zone, but the rate of extraction may not be great enough to maintain optimum plant growth during the periods of peak demand.

Taylor *et al.* (9) and Vasquez *et al.* (10) postulated that soil water extraction by plants is a function of the actively growing roots only when the soil is uniformly moist throughout the profile. More water is removed from the shallow depths, where root activity is greatest, and the distance water must move is the least when the soil profile is uniformly moist throughout. As the surface soil moisture is decreased a greater water suction is required thereby resulting in a decreased volume which can be removed from shallow depths. For the water demand of the cotton to be met, greater amounts of water have to be extracted from deeper depths where root activity is lower but the volume of water is greater. Then equal or greater amounts of water are removed from deeper depths at a given time interval. After an irrigation or rainfall, larger amounts of water are removed each day from progressively lower depths.

Marani *et al.* (4) studied the effects of a single irrigation on the production of cotton and concluded that cotton irrigated at the beginning of flowering was found to be the most advantageous, increasing the yield of lint more than the other treatments. This irrigation increased the number of bolls and also boll size. An irrigation applied at the initiation of flower bud formation was less effective in increasing the number of bolls. This was because of an excessive rate of shedding of young bolls during the peak of flowering in July. A late irrigation applied at the peak of flowering was the least effective in increasing boll number. It did improve boll size, staple length, and fiber maturity.

Experimental Methods

The experiment, "Effect of Irrigation on the Response of Cotton to Fertilization," was located on Richland silt loam soil that was landformed for row irrigation in 1955. After being leveled, the soil was limed with one ton of dolomitic limestone per acre. In 1959 an additional ton per acre was applied. The experimental design used was a split plot with irrigation treatments as the main plot. The irrigated and non-irrigated subplots were four 40-inch rows measuring 85 feet in length. Four replications were used. The two center rows were harvested for yield measurements. The cotton plots received nitrogen at the rate of 0, 60, 120, and 180 pounds per acre in all possible combinations with 60 and 90 pounds of P_2O_5 and K_2O. Ammonium nitrate was the source of nitrogen, superphosphate the source of P_2O_5, and muriate of potash the source of K_2O. Gated pipe was used to flood the irrigated plots with water until the soil reached field capacity. Soil samples were taken at 6-inch increments to a depth of 30 inches throughout the growing season, and when the available soil moisture dropped to approximately 50 percent the irrigated plots were watered to bring the moisture level to field capacity. The available soil moisture was determined to the effective depth that plant roots were extracting soil moisture. The moisture content of the 0- to 30-inch depth was determined by oven drying soil samples for 24 hours at 110° Centigrade. The moisture was expressed on an oven dry weight basis.

Stardel cotton was used throughout the years of testing. The cotton was planted by hill-dropping on a 12-inch spacing and thinned to leave two to three plants per hill. Planting was done at the earliest opportunity in May of each year. Karmex DL pre-emerge herbicide, post emergence oil, and flaming were used as conditions warranted. Except in 1962, the cotton was hand harvested for yield. This experiment was rotated each year with another experiment. The nitrogen fertility levels were the same for both experiments. They were held in the same plots throughout the years of testing.

Experimental methods for the study, "Yield of Cotton as Influenced by Water Regime and Plant Population," were the same as the above experiment except that this experiment was on Olivier silt loam soil and was fertilized at the rate of approximately 130 pounds of nitrogen and 72 pounds each of P_2O_5 and K_2O per acre.

The following moisture regime and plant populations were studied:

A. Water regime.
   1. Not irrigated.
   2. Irrigated when available moisture reached 25 percent level.

B. Plant populations.
  1. One plant per hill 12 inches apart in the drill (13,100 plants per acre).
  2. Three plants per hill 12 inches apart in the drill (39,200 plants per acre) .
  3. Six plants per hill 12 inches apart in the drill (78,400 plants per acre).

The experimental design was a split plot with the water regime as the main plot and plant populations as the subplot. The main plots were 12 rows 200 feet long; the subplots were four rows 200 feet long. The two inside rows of the subplot were harvested for yield. A buffer zone was maintained between irrigated and non-irrigated plots. Soil samples were taken at 6-inch increments to a depth of 30 inches throughout the growing season. When the available soil moisture reached the designated level these plots were irrigated to bring the moisture level to field capacity.

Effect of Irrigation on the Response of Cotton to Fertilization

Data for 1958

Yield Response: Yield increases from nitrogen on irrigated plots in 1958 (Fig. 1) were not significant above the 60 pound per acre rate

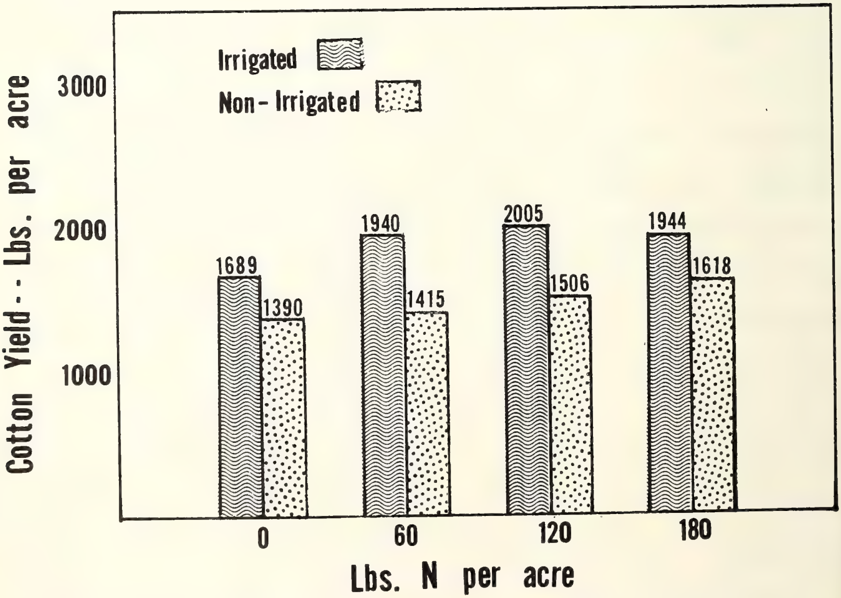

FIGURE 1.—Response of cotton to irrigation and nitrogen fertilization, 1958.

of nitrogen application. There were no significant yield increases of seed cotton at any nitrogen level on plots that did not receive irrigation. At the 60 pound rate of nitrogen application, irrigated cotton produced 1,940 pounds of seed cotton per acre while plots that did not receive any irrigation water produced 1,415 pounds of seed cotton per acre, 525 pounds less than the irrigated plots. Use of 90 pounds of phosphate and/or potash did not produce yields significantly higher than 60 pounds of these nutrients under either irrigated or non-irrigated conditions.

Rainfall: Total rainfall (20.2 inches) and distribution were adequate during April, May, June, and through July 29 (Fig. 2). Two inches of irrigation water was applied July 31 in order to maintain soil moisture at the 50 percent level. Irrigation was necessary again on August 11, but it was followed by 2.1 inches of rain, nullifying possible beneficial effects of the last irrigation. During the latter part of August and September large amounts of rainfall caused a considerable amount of boll rot.

Soil Moisture Trends: The soil was at field capacity July 9 when soil moisture determination was begun. By July 22 the cotton roots were definitely extracting moisture to a depth of 18 inches (Fig. 3) with the greater amount being extracted from the shallower depth and decreasing as depth increased. On August 11, at the 0- to 6-inch depth, the available soil moisture was 12 percent. For the remainder of the growing season the soil moisture was at or approaching field capacity.

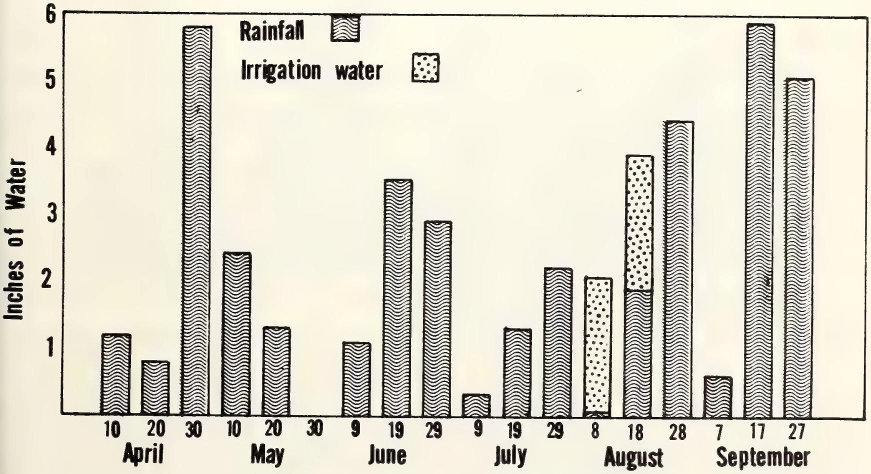

FIGURE 2.—Rainfall distribution by 10-day periods, and irrigation water applied to cotton, 1958.

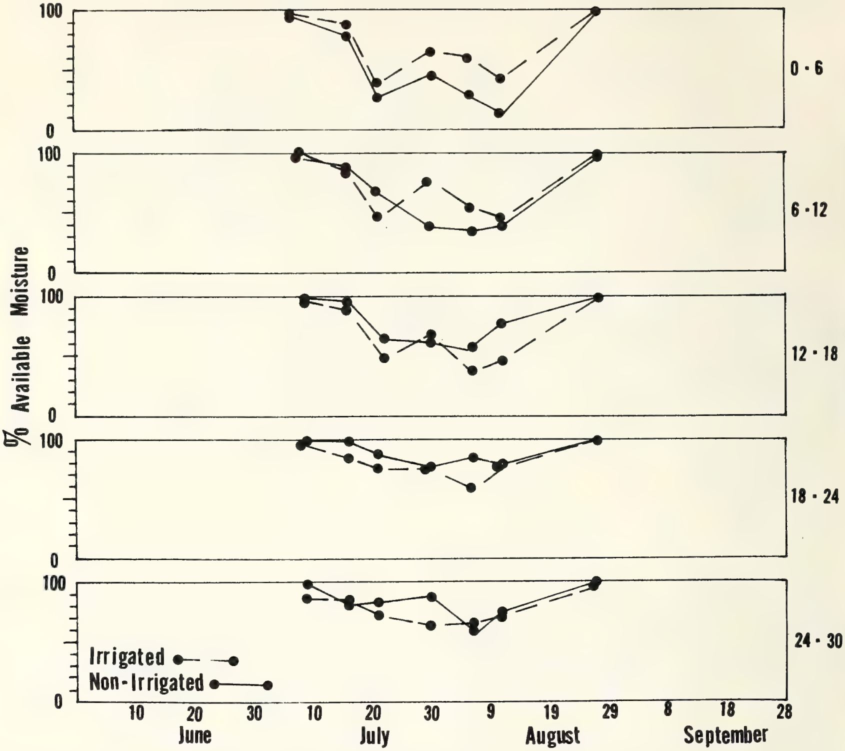

FIGURE 3.—Soil moisture trends for irrigated and non-irrigated cotton from 0- to 30-inch depth, 1958.

Data for 1959

Yield Response: Cotton yields were increased by nitrogen applications up to 120 pounds per acre (Fig. 4) on irrigated and non-irrigated plots. Although irrigation did increase yields by 305 pounds of seed cotton per acre the difference was not significant. There was an interaction between irrigation and nitrogen application. Nitrogen with irrigation produced larger yields than nitrogen without irrigation. Use of 90 pounds of phosphate and/or potash did not produce yields significantly higher than 60 pounds of these nutrients under either irrigated or non-irrigated conditions.

Rainfall: During the month of May and through June 9 (Fig. 5) 11.5 inches of rain fell, which was above average for this period. For the 12-day period from June 10 through June 21 there was no rainfall. The total rainfall and distribution for the remainder of the growing season was adequate except for a 12-day period from August 8 through August 19. Two inches of irrigation water was applied to the designated

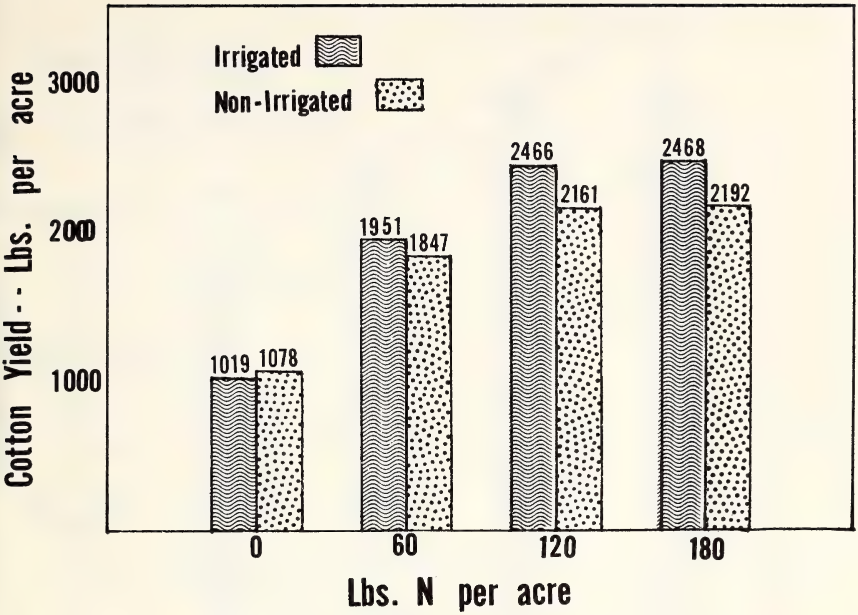

FIGURE 4.—Response of cotton to irrigation and nitrogen fertilization, 1959.

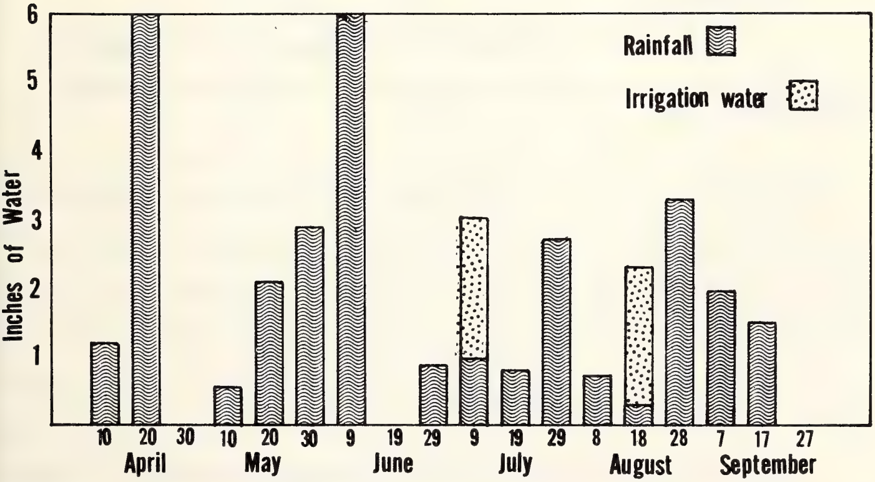

FIGURE 5.—Rainfall distribution by 10-day periods, and irrigation water applied to cotton, 1959.

plots on July 9. After application of the water, .8 inch of rain fell, possibly eliminating some benefits of the irrigation. A second irrigation was required on August 12. Rainfall was adequate for the remainder of the growing season.

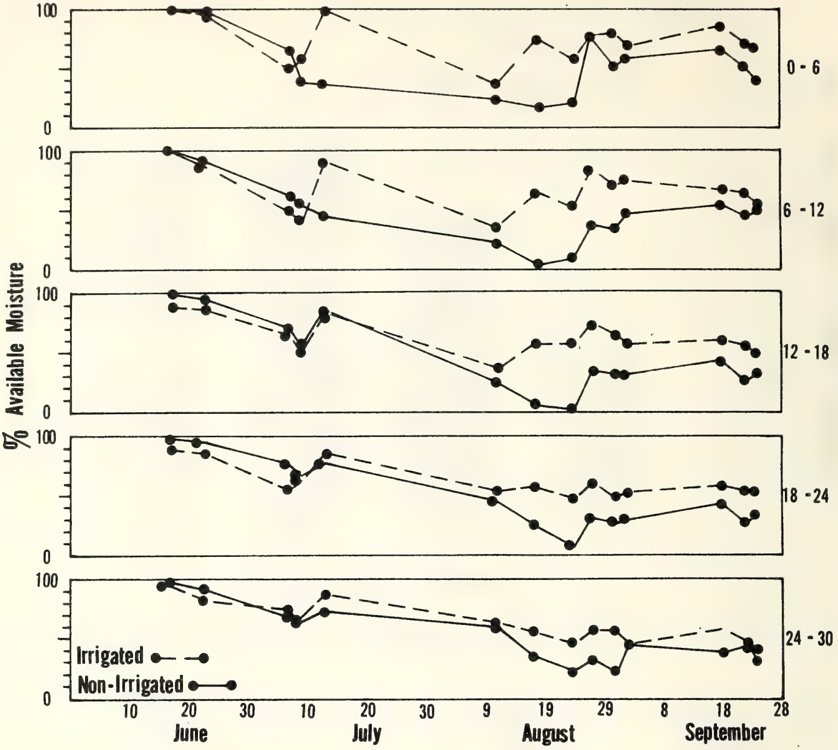

FIGURE 6.—Soil moisture trends for irrigated and non-irrigated cotton from 0- to 30-inch depth, 1959.

Soil Moisture Trends: Non-irrigated plots had one extended dry period of 8 days from August 15 to August 23 (Fig. 6) at which time available soil moisture was almost completely depleted down to a depth of 24 inches. For the remainder of the growing season soil moisture was adequate. This appears to be the reason irrigated plots yielded only 305 pounds more seed cotton than non-irrigated plots.

Data for 1960

Yield Response: Yield of cotton on irrigated plots was very high—3,806 pounds of seed cotton per acre at the 120 pound level of nitrogen application (Fig. 7). Non-irrigated plots at the same rate of nitrogen application yielded 1,869 pounds, a difference due to irrigation of 1,937 pounds per acre. Cotton on irrigated plots responded to nitrogen applications up to the 120 pound level. On non-irrigated plots there was no yield response to nitrogen fertilization. There was an interaction between irrigation and nitrogen application. Use of 90 pounds of phosphate

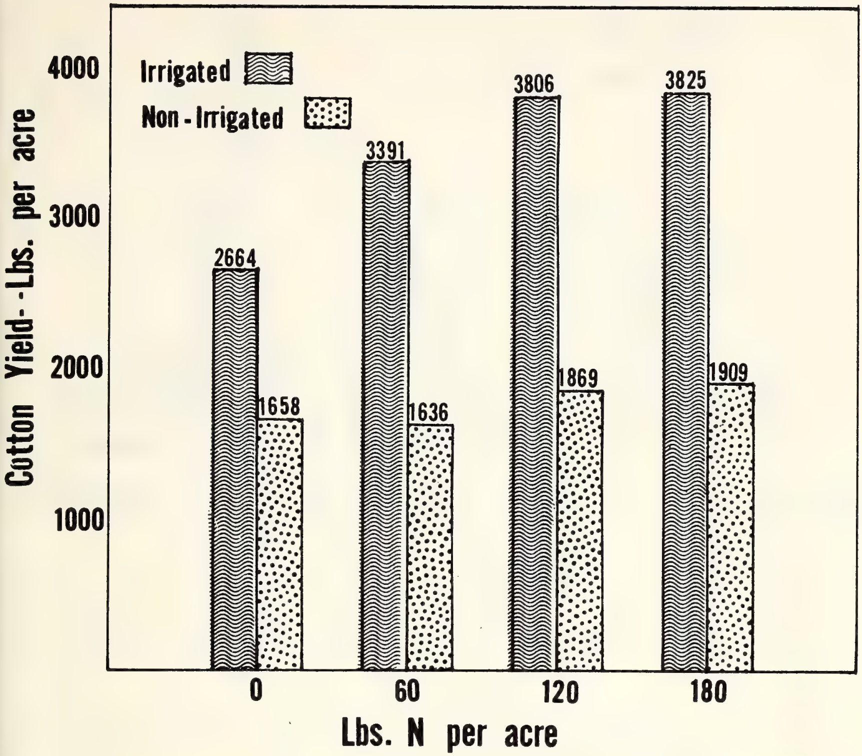

FIGURE 7.—Response of cotton to irrigation and nitrogen fertilization, 1960.

and/or potash did not produce yields significantly higher than 60 pounds of these nutrients under either irrigated or non-irrigated conditions.

Rainfall: Total rainfall and distribution was very inadequate throughout the entire growing season (Fig. 8). For the months of April and May and through June 24 rainfall was considerably below normal, the total amount being 7 inches. There was a period from July 20 through August 9 that received only .4 inch of rain. In order to maintain moisture at the 50 percent level on irrigated plots, 2 inches of water was applied on July 14 and August 1. The latter part of August was extremely wet, the total amount of rainfall being 9.2 inches.

Soil Moisture Trends: Soil moisture data indicate that cotton roots were extracting some moisture from a depth of 30 inches in the soil (Fig. 9). The greater amount of the moisture was extracted from the upper zone of soil and decreased with depth. From the 0- to 12-inch depth most of the soil moisture was extracted approaching the 0 percent available moisture level.

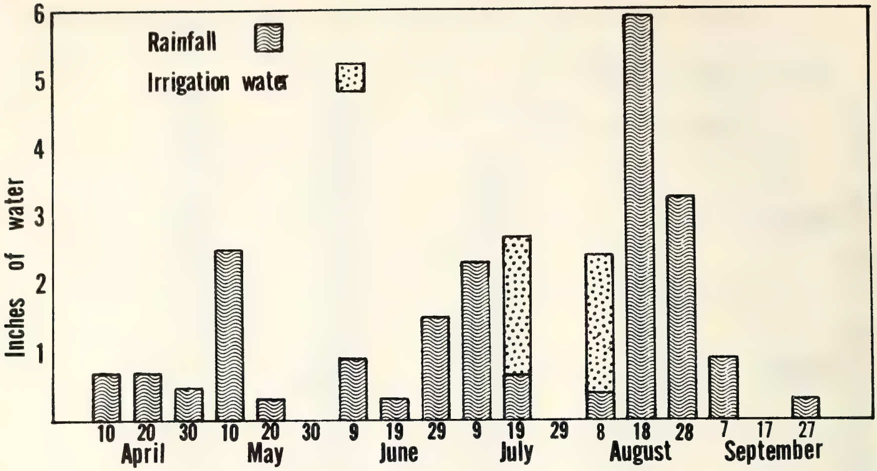

FIGURE 8.—Rainfall distribution by 10-day periods, and irrigation water applied to cotton, 1960.

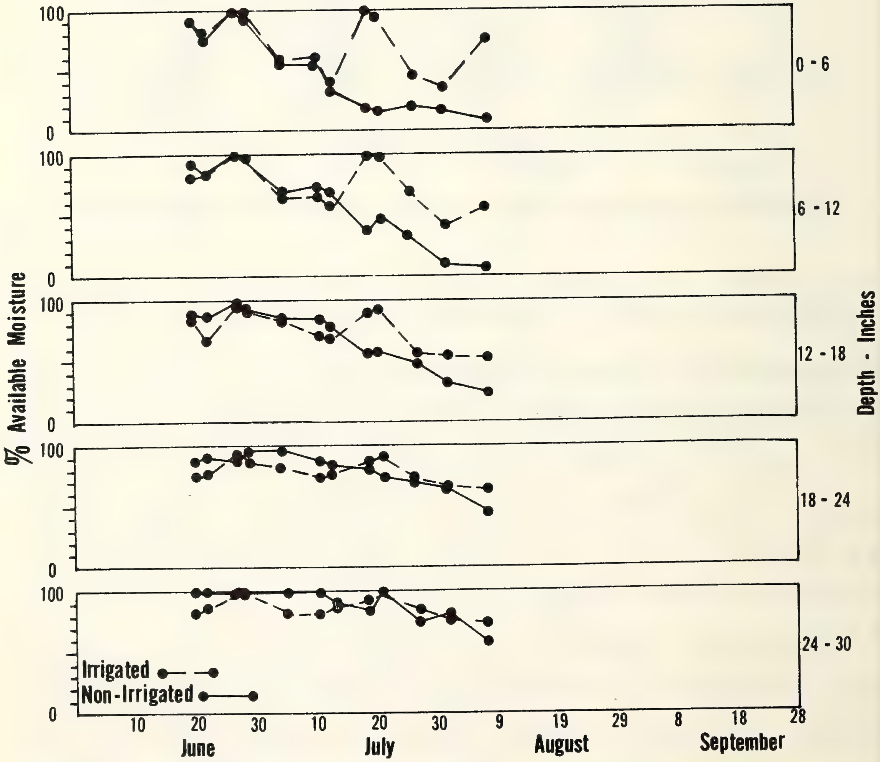

FIGURE 9.—Soil moisture trends for irrigated and non-irrigated cotton from 0- to 30-inch depth, 1960.

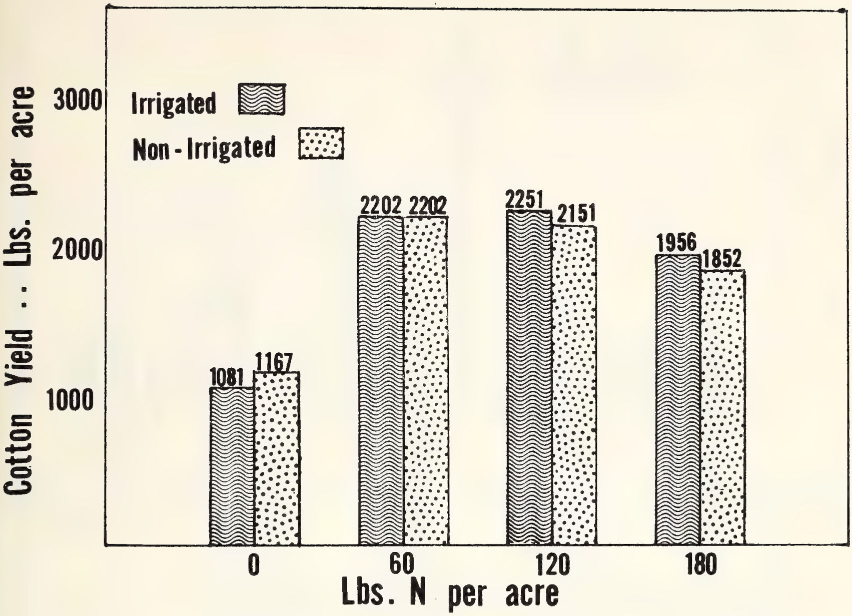

FIGURE 10.—Response of cotton to irrigation and nitrogen fertilization, 1961.

Data for 1961

Yield Response: Ample rainfall in 1961 made it unnecessary to water plots that were to have been irrigated. As a consequence, yields were substantially the same at each nitrogen level (Fig. 10). There were no increases from nitrogen application above the 60 pound per acre rate, nor were there any increases from the addition of 90 pounds of phosphate and/or potash in comparison with the 60 pound level of these nutrients.

Rainfall: During the first part of the growing season, May 2 through June 14, .7 inch of rain fell, (Fig. 11). For the remainder of the season there was ample rainfall and the distribution was good. As a consequence it was unnecessary to water plots that were to have been irrigated.

Soil Moisture Trends: Soil moisture was adequate for maximum crop yields throughout the growing season (Fig. 12). From June 12 through August 1 soil moisture was at or approaching field capacity. During the middle of August plant roots were extracting moisture from a depth of only 12 inches.

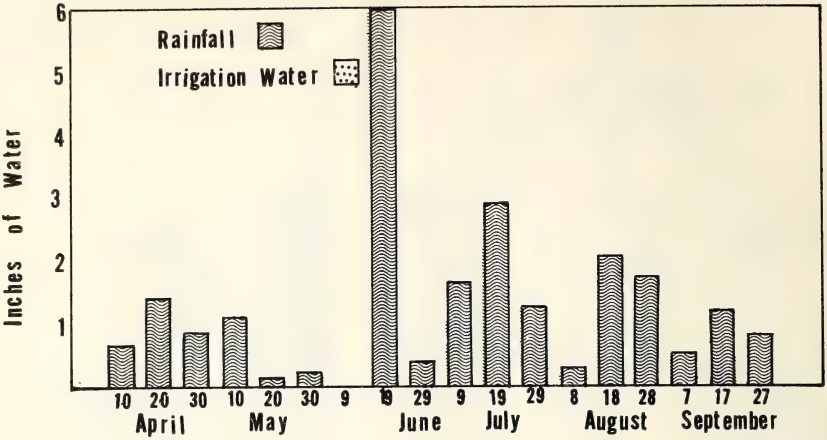

FIGURE 11.—Rainfall distribution by 10-day periods, and irrigation water applied to cotton, 1961.

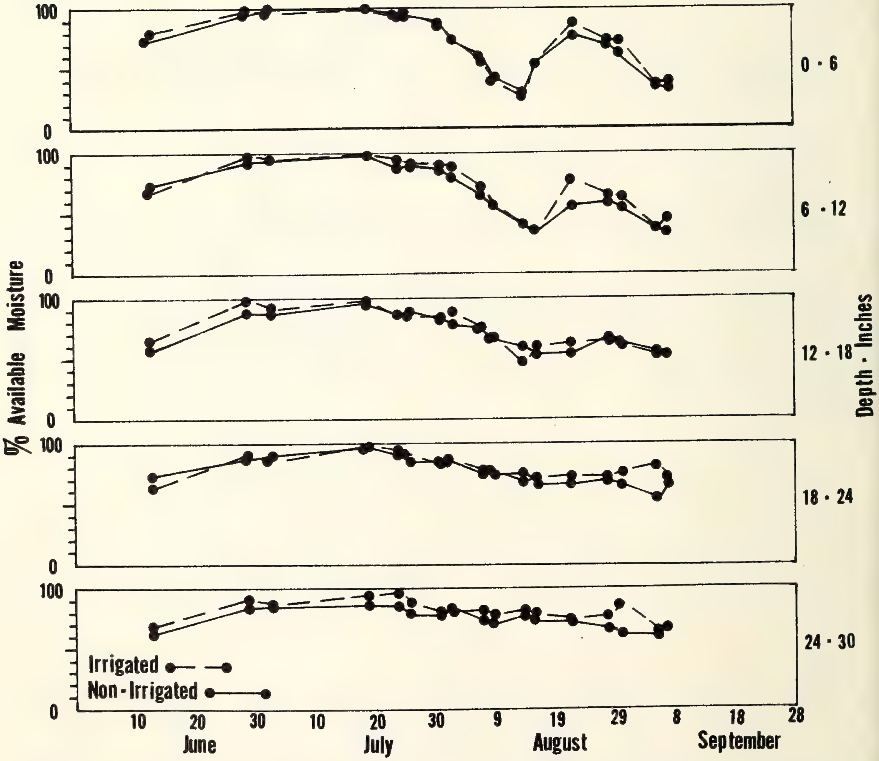

FIGURE 12.—Soil moisture trends for irrigated and non-irrigated cotton from 0- to 30-inch depth, 1961.

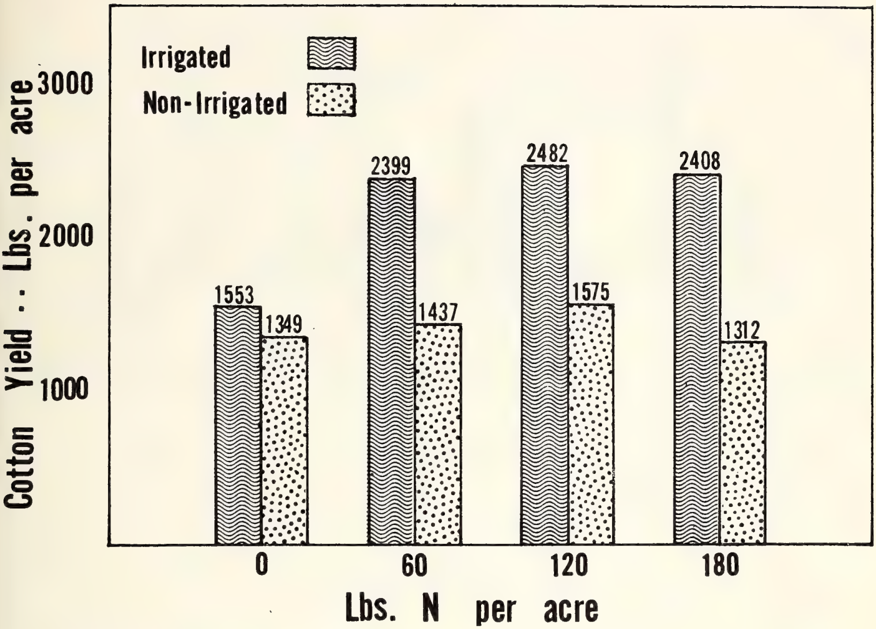

FIGURE 13.—Response of cotton to irrigation and nitrogen fertilization, 1962.

Data for 1962

Yield Response: Irrigation significantly increased cotton yields at each nitrogen level (Fig. 13). The yield increase ranged from 204 pounds of seed cotton where no nitrogen was added to 907 pounds for the 120 pound rate. The average yields for all nitrogen treatments were 1,418 and 2,211 pounds for the non-irrigated and irrigated cotton, respectively.

The interaction of nitrogen and irrigation was highly significant. The yield of cotton fertilized with nitrogen under irrigation was significantly increased while the non-irrigated cotton responded very little to nitrogen rates. Yield increases under irrigation were similar for all rates of nitrogen from 60 to 180 pounds per acre, the average increase from these nitrogen rates being 877 pounds of seed cotton. Use of 90 pounds of phosphate and/or potash did not produce yields significantly higher than 60 pounds of these nutrients under either irrigated or non-irrigated conditions.

Rainfall: Rainfall was very erratic throughout the growing season (Fig. 14). For the month of April more than an average amount of

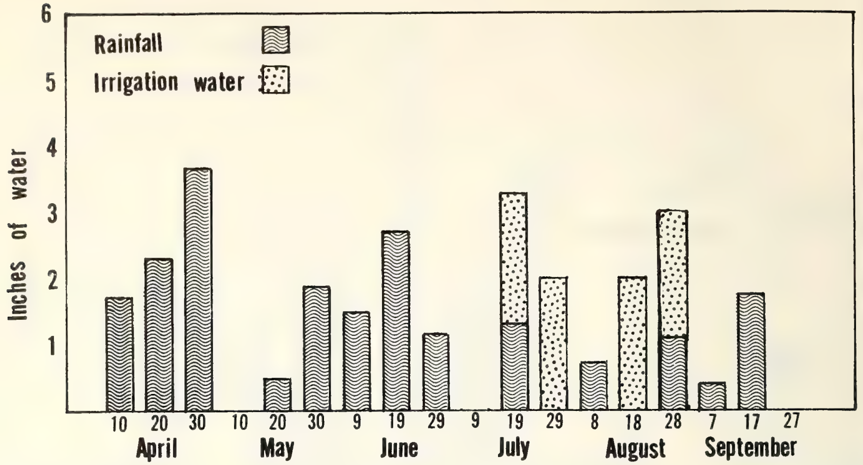

FIGURE 14.—Rainfall distribution by 10-day periods, and irrigation water applied to cotton, 1962.

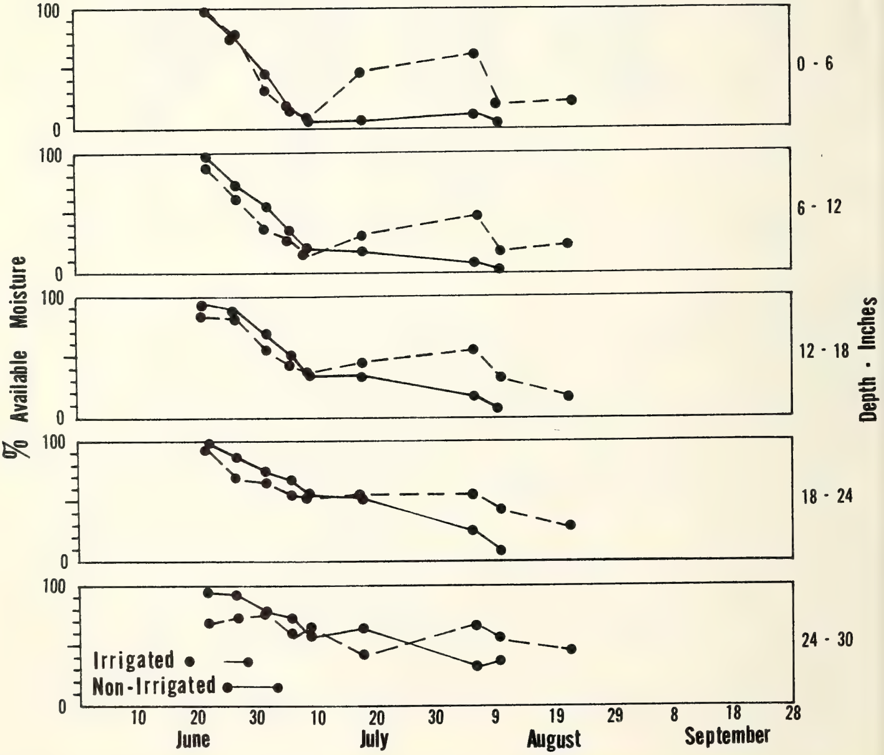

FIGURE 15.—Soil moisture trends for irrigated and non-irrigated cotton from 0- to 30-inch depth, 1962.

rain fell, a total of 7.5 inches. The month of May was very dry with .5 inch of rain. June was an extremely wet month with a very uniform rainfall pattern. The remainder of the growing and fruiting season was very dry, and the small amount of rain that fell was very irregular. From June 29 through July 9 there was no rainfall. On July 10, July 24, August 10, and August 27 the cotton was irrigated, with 2 inches of water being applied at each irrigation. Through the important growing and fruiting season, from June 29 through September 17, only 3.5 inches of rain fell. There was an excellent harvesting season with extremely little lodging and boll rot.

Soil Moisture Trends: At the first soil moisture sampling, June 22, soil throughout the profile was at field capacity (Fig. 15). By July 9 at the 0- to 6-inch depth the soil moisture had been extracted down to 10 percent; at the 6- to 12-inch depth, 20 percent; at the 12- to 18-inch depth, 35 percent; at the 18- to 24-inch depth, 55 percent; and at the 24- to 30-inch depth, 65 percent. As the depth of sampling increased the percentage of soil moisture extracted decreased progressively with depth. The soil moisture had been extracted to the wilting point by August 10 down to a depth of 12 inches on plots that did not receive irrigation. From 12 to 24 inches, the available soil moisture had been extracted down to the 10 percent level. Due to extremely hot temperatures and low humidity more irrigation was required in 1962 than in the previous years.

Summary of Results

The amount of rainfall and irrigation supplied to cotton from 1958 through 1962 is given in Table 1. The total amount of rainfall supplied to the crop from April 1 through August 31 varied from 18.8 inches in 1962 to 34.1 inches in 1959. In 1959, the year with the largest amount of rainfall, two irrigations were required, while in 1961, which received 13.3 inches less rainfall, irrigation was not needed. This indicates that the distribution of rainfall is important, especially during the critical months of July and August. During these months the cotton plant requires more water for maximum production than at any other time. Two irrigations, one in July and one in August, were required in 1958, 1959, and 1960. In 1961 irrigation was not required due to the total amount and distribution of rainfall. In 1962 four irrigations were required, two each in July and August. The average amount of rainfall plus irrigation for July and August for the years 1958 through 1962 was 13.9 inches.

Supplemental irrigation increased cotton yields for the years 1958, 1960, and 1962. The amount and distribution of rainfall in 1961 made it unnecessary to irrigate. Yield increase due to supplemental irrigation for the 5 years of testing ranged from 0 to 1,937 pounds of seed cotton per acre.

TABLE 1.—Summary of Water Supplied to the Soil by Rainfall and Irrigation During Growing Seasons, 1958-1962, Winnsboro, La.

	1958	1959	1960	1961	1962	5 yr. avg.
Rainfall, inches						
April-August total	28.8	34.1	22.0	20.8	18.8	24.9
June	7.63	7.29	2.74	7.05	5.31	6.00
July	3.18	4.66	3.12	5.49	1.32	3.55
August	6.44	4.97	10.42	4.02	2.22	5.61
Total, June-August	17.25	16.92	16.28	16.56	8.85	15.17
Percent of season total in						
July	11.1	13.7	14.2	26.4	7.0	14.3
August	22.4	14.6	47.4	19.3	11.8	22.6
Irrigation water supplied, inches	4.0	4.0	4.0	0	8.0	4.0
Total water supplied, inches	32.8	38.1	26.0	20.8	26.8	28.9
Percent of total water supplied by irrigation	12.2	10.5	15.4	0	30.0	13.9
Number of irrigations, June - August	2	2	2	0	4	1.6
Number of irrigations in						
June	0	0	0	0	0	0
July	1	1	1	0	2	1
August	1	1	1	0	2	1

Average yields for the 5 years at the 120 pound level of nitrogen were 2,602 and 1,852 pounds of seed cotton for the irrigated and non-irrigated plots respectively (Fig. 16). This is an average increase of 750 pounds of seed cotton per acre due to irrigation.

In 2 of the 5 years of testing under irrigated conditions, yield increases were obtained by nitrogen application up to the 120 pound per acre level. The other 3 years, 60 pounds of nitrogen produced yields comparable to higher rates of nitrogen applications. In 4 of the 5 years of testing, the 120 and 180 pound rates of nitrogen produced comparable yields. In 1961, the 180 pound rate of nitrogen decreased yields below that produced at the 120 pound rate. In all the years of testing there was no decrease in yield from the application of 120 pounds of nitrogen per acre, although in 3 of these years there was no increase in yields.

In 3 dry years of testing, 1958, 1960, and 1962, on non-irrigated plots there were very small increases in the yield of cotton by the application of nitrogen. Nitrogen applications up to the 120 pound rate resulted in yield increases in 1959, but in 1960 there were no increases above the 60 pound level.

Rainfall and distribution for the 5 years covering this study ranged from excellent to extremely poor. It appears that the distribution of rainfall is as important as the total rainfall during the growing and fruiting season.

The response of cotton yields to nitrogen fertilization is directly correlated to soil moisture. Under extremely dry conditions only small increases resulted from nitrogen application, while under favorable con-

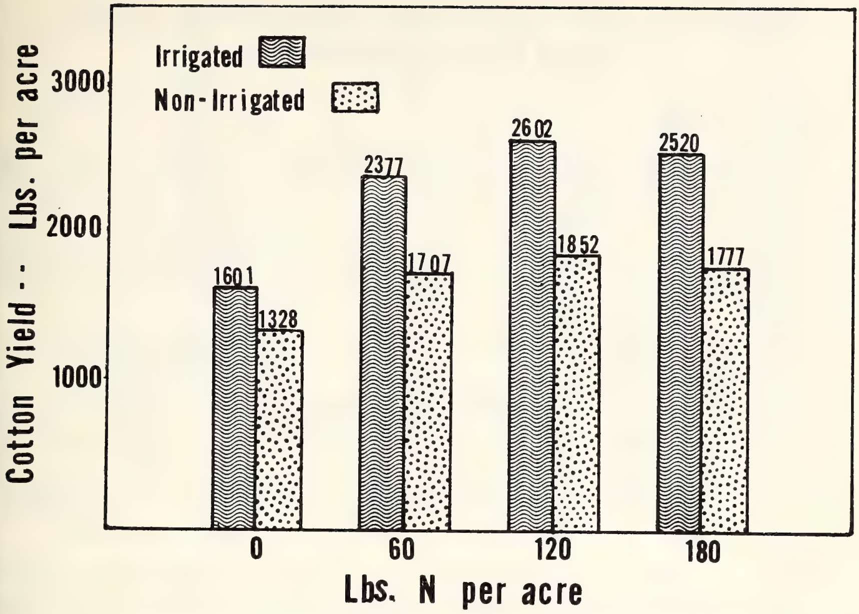

FIGURE 16.—Response of cotton to irrigation and nitrogen fertilization, five-year average, 1958-62.

ditions yields were increased by the addition of nitrogen up to the 120 pound level.

In years of inadequate or poorly distributed rainfall, cotton roots definitely extracted moisture from a depth of 30 inches in the soil. The greater amount of moisture was extracted from the 0- to 6-inch depth, and the amounts decreased progressively with greater depths. In wet years the plants' supply of water was supplied largely from the topsoil. For the water demand of the plant to be met during dry years, greater amounts of water had to be extracted from lower depths where there were fewer roots but more available water. It was evident that cotton plants extract water from below the 18-inch depth, but not enough for optimum growth during the critical period of blooming and boll development. After each watering by irrigation or rainfall, the same pattern of moisture depletion occurred.

Yield of Cotton as Influenced by Water Regime and Plant Population

Data for 1958

Yield Response: Irrigation increased cotton yields over plots that were not irrigated (Fig. 17). The average yield increase due to irrigation was 975 pounds of seed cotton per acre. As an average of all plant populations, there was no difference in yield between the plots that were maintained at the 25 percent and the 50 percent levels of available soil moisture.

On non-irrigated plots one stalk per hill produced higher yields than three or six plants.

On plots that contained one and three plants per hill 12 inches apart in the drill and where soil moisture was maintained at 25 percent and 50 percent availability, there were no differences in yield. With a plant population of six plants per hill there was a reduction in yield where the soil moisture was maintained at the 25 and 50 percent levels.

Rainfall: The total amount of rainfall (Fig. 18) during the cotton growing season was ample for maximum production but the distribution was poor. There were two periods from June 29 to July 9 and from July 29 to August 8 in which only .5 inch of rain fell. During the remainder of the growing season the distribution of water was good,

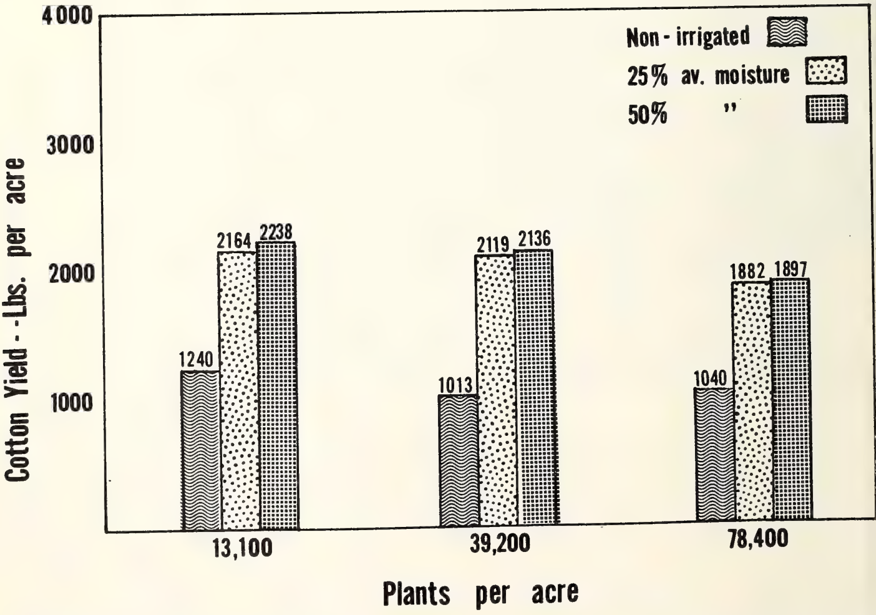

FIGURE 17.—Response of cotton to levels of soil moisture and plant population, 1958.

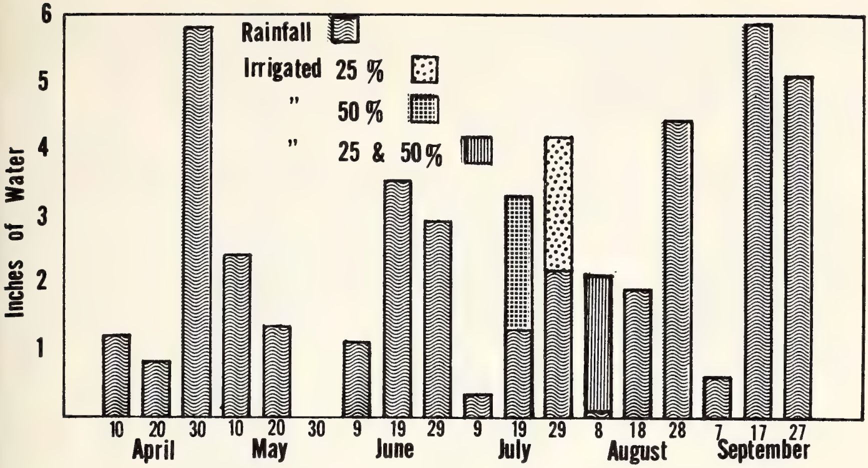

FIGURE 18.—Rainfall distribution by 10-day periods, and irrigation water applied to cotton, 1958.

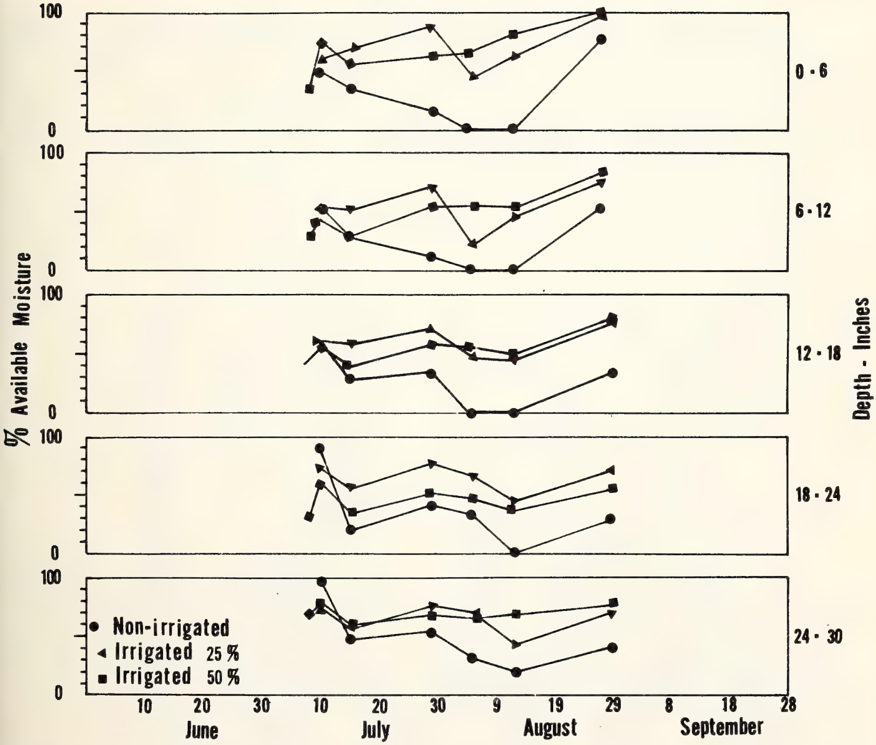

FIGURE 19.—Soil moisture trends for irrigated and non-irrigated cotton from 0- to 30-inch depth, 1958.

with the latter part of the growing season receiving too much rainfall. On July 21 and August 7 the plots that were maintained at the 25 percent level of available soil moisture were irrigated. Plots kept at the 50 percent level were irrigated July 18, July 30, and August 7.

Soil Moisture Trends: When sampling for moisture determination was begun July 8 (Fig. 19) the cotton roots were already extracting moisture down to the 30-inch depth. By August 5, on plots that were not irrigated all available soil moisture had been depleted to the 18-inch depth. The soil moisture on non-irrigated plots was nearly depleted down to 30 inches until the last of August, when more than average amounts of rain fell, thereby partially recharging the soil with moisture to the 30-inch depth.

Due to times of irrigation and rainfall, there were times when the plots that were to be irrigated when the soil moisture reached the 25 percent level contained more moisture than the plots which were irrigated when the soil moisture reached the 50 percent level.

Data for 1959

Yield Response: Due to the amount and distribution of rainfall (Fig. 20) there were no significant differences among irrigations or plant populations. On plots that had a plant population of six plants per hill and were irrigated at the 50 percent level there was a reduction in yield which approached significance.

Rainfall: From April 20 through May 10, a period of 20 days, .6 inch of rain fell (Fig. 21). May 11 through June 9 was very wet with a total of 11 inches of rain. From June 10 through June 19 was a period of 10 days that did not receive any rain. For the remainder of the growing season, small but consistent amounts of rain fell every 10 days ranging from .3 inch to 3.3 inches. During this period when the designated plots were irrigated, rain fell immediately following irrigation, which possibly minimized the effect of irrigation. The plots that were to be irrigated at the 25 percent available moisture level received irrigation July 9 and August 11. At the 50 percent level, plots were irrigated July 2, July 20, August 7, and August 14.

Soil Moisture Trends: Sampling for soil moisture was begun June 14 (Fig. 22), at which time soil moisture was at or approached field capacity. By July 13 on non-irrigated plots the soil moisture was approaching wilting point down to the 24-inch depth with the 6-inch depth having more moisture than the lower depth. For the remainder of the fruiting season the soil moisture from the 6-inch to the 24-inch depth was at the wilting point. The 0- to 6-inch depth contained small amounts of available soil moisture, thereby reflecting the small but uniform distribution of rainfall. Soil moisture on the plots irrigated at 25 and 50

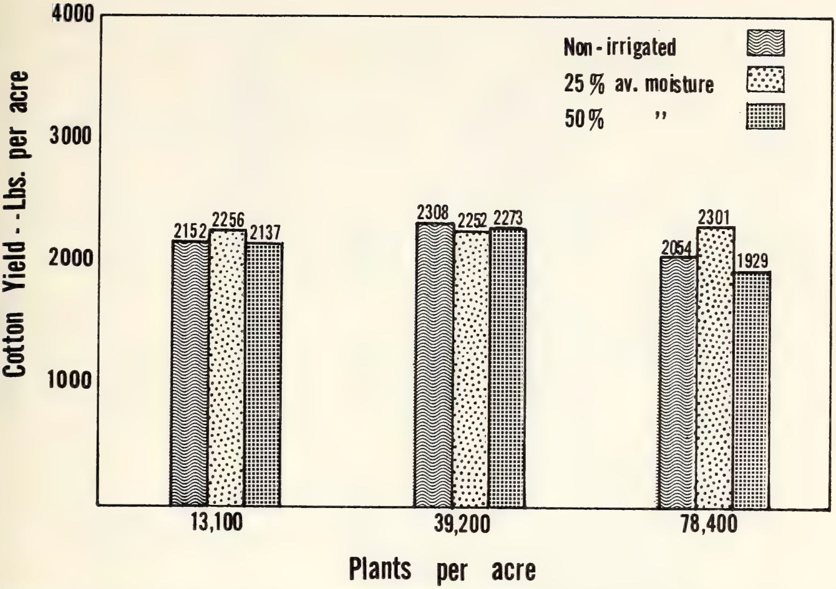

FIGURE 20.—Response of cotton to levels of soil moisture and plant population, 1959.

percent levels had been extracted down to the 30-inch depth with the greater amount of moisture being extracted from the 0- to the 24-inch depth.

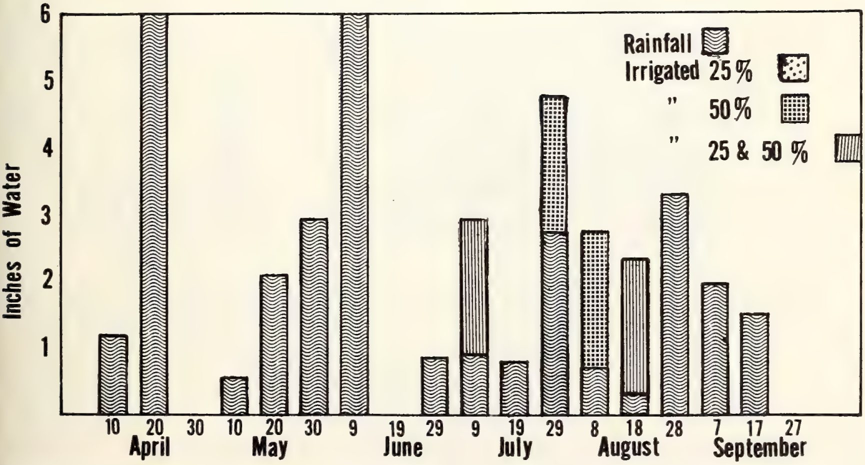

FIGURE 21.—Rainfall distribution by 10-day periods, and irrigation water applied to cotton, 1959.

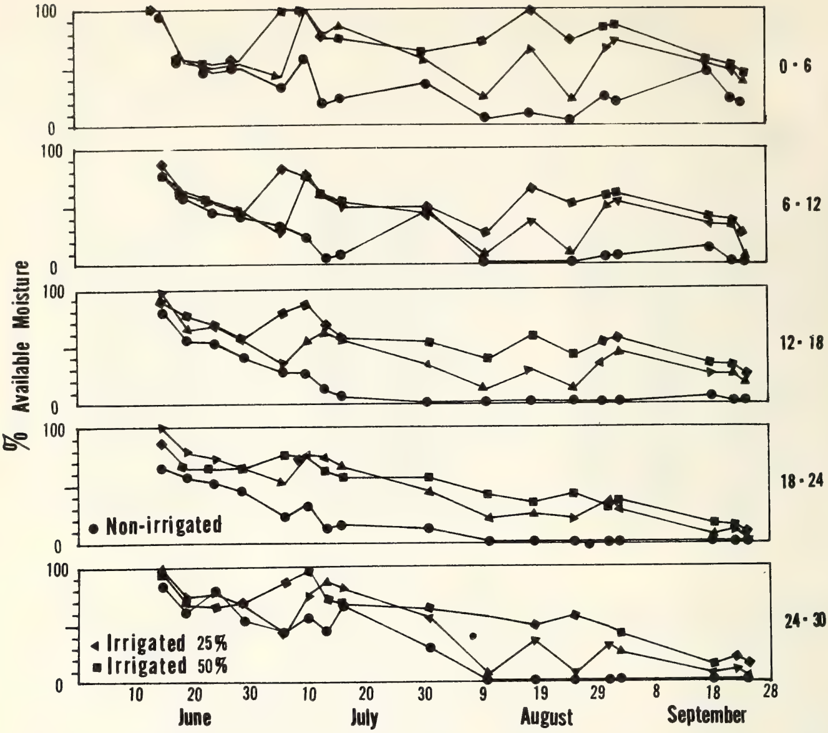

FIGURE 22.—Soil moisture trends for irrigated and non-irrigated cotton from 0- to 30-inch depth, 1959.

Data for 1960

Yield Response: Irrigation increased yields by 1,762 pounds of seed cotton per acre (Fig. 23). One plant per hill every 12 inches outyielded 3 and 6 plants per hill at all moisture levels. Under irrigated conditions, six plants per hill significantly reduced yields. Cotton on these plots had more lodging and boll rot, which probably accounts for the reduction in yield. There was a significant irrigation and plant population interaction. Under irrigation, as plant populations increased there was a reduction in yield.

Rainfall: The distribution of rainfall was very inadequate for the production of cotton (Fig. 24). The latter half of May through the middle of June was very dry. The last half of June through July 9, ample rain fell for optimum production. In order to maintain soil moisture at the 50 percent level, designated plots were irrigated July 11, July 28, and August 4. The 25 percent moisture level was maintained by irrigating July 25 and August 4. The last half of August was very wet with conditions conducive to boll rot.

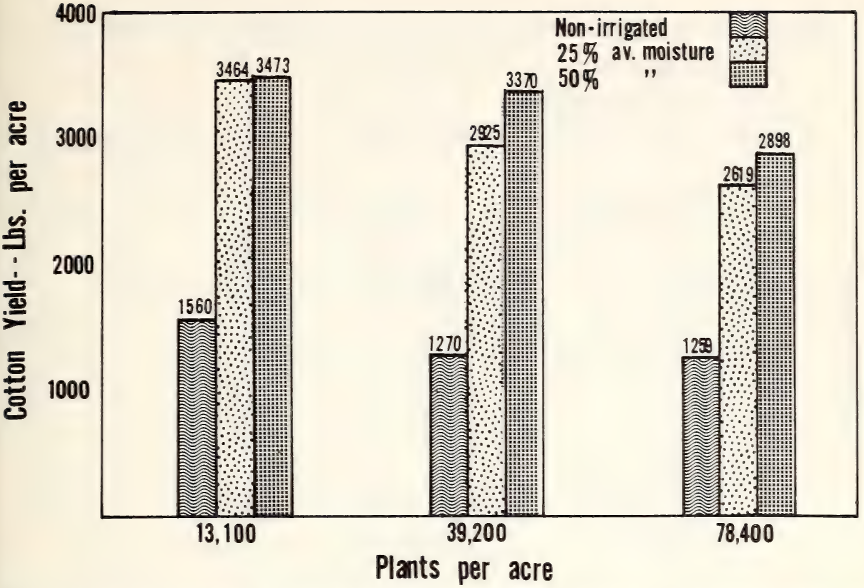

FIGURE 23.—Response of cotton to levels of soil moisture and plant population, 1960.

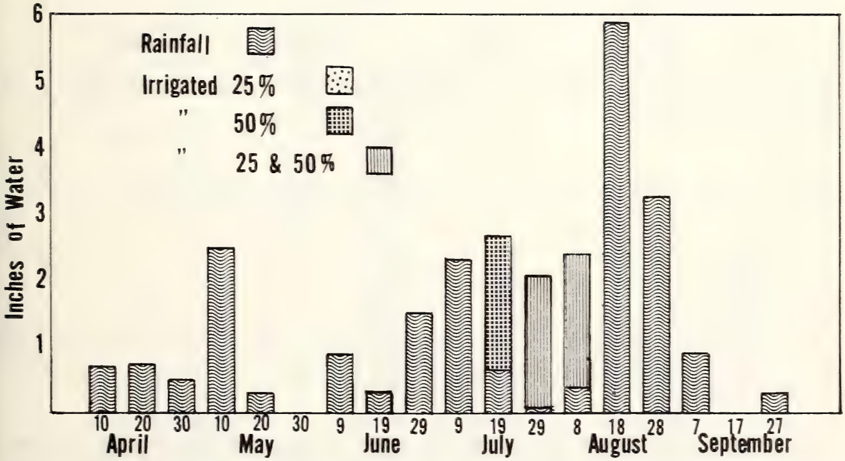

FIGURE 24.—Rainfall distribution by 10-day periods, and irrigation water applied to cotton, 1960.

Soil Moisture Trends: Soil moisture during the entire growing season (Fig. 25), with the exception of the last of August, was never at field capacity. This was due to the dry April and May. By July 18 and through August 9 the non-irrigated plots were at wilting point to a depth of 12 inches. The plant roots were extracting moisture to 30

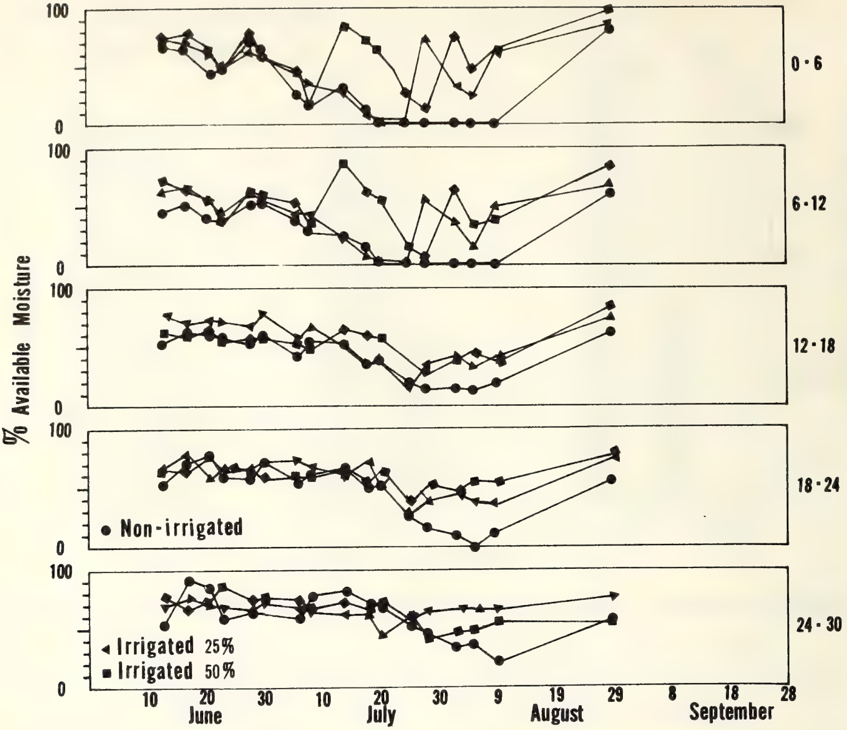

FIGURE 25.—Soil moisture trends for irrigated and non-irrigated cotton from 0- to 30-inch depth, 1960.

inches but the amount was not enough to supply the requirement of the plants.

Data for 1961

Yield Response: Due to the amount and distribution of rainfall there were no yield differences among the irrigations or plant populations (Fig. 26).

Rainfall: With the exception of the last of May through the first half of June, rainfall and distribution was ample for cotton production (Fig. 27). Due to rainfall the plots that were designated to be irrigated at the 25 percent level did not require irrigation. The 50 percent available soil moisture plots were irrigated on August 16 and September 9. Rainfall immediately after each irrigation probably accounts for the lack of yield response to irrigation.

Soil Moisture Trends: Throughout the soil profile to a depth of 30 inches, soil moisture was ample for maximum production of cotton

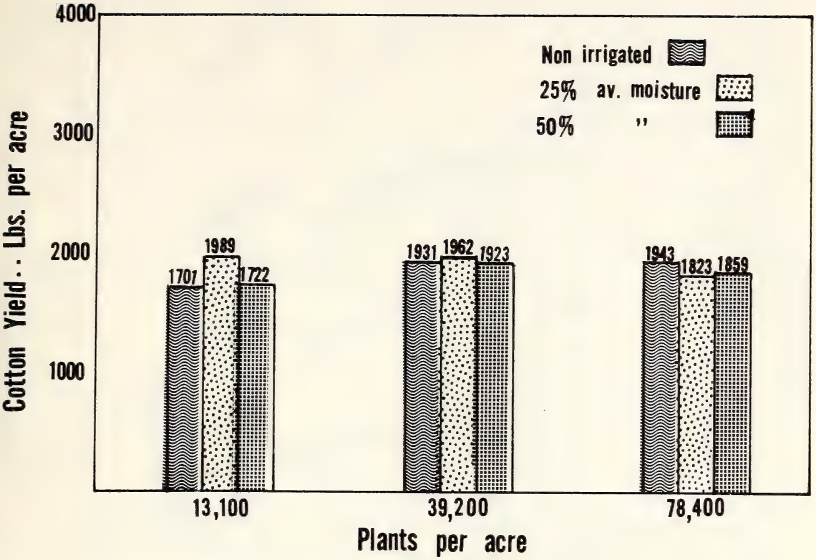

FIGURE 26.—Response of cotton to levels of soil moisture and plant population, 1961.

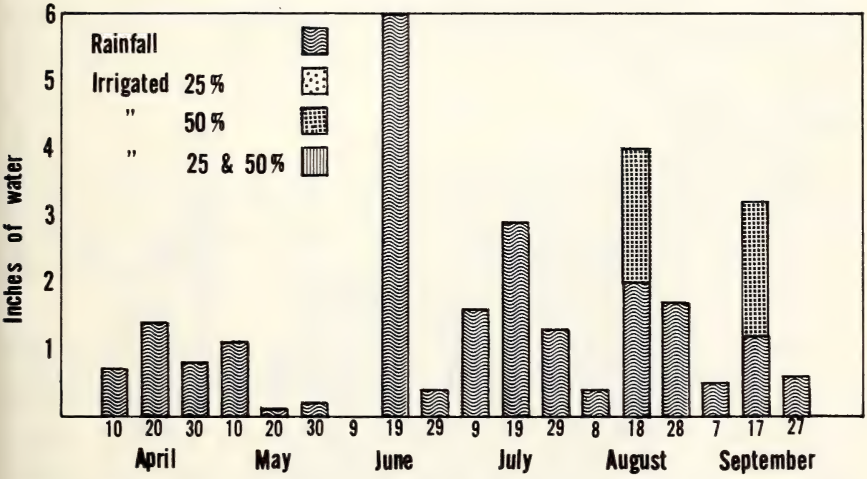

FIGURE 27.—Rainfall distribution by 10-day periods, and irrigation water applied to cotton, 1961.

(Fig. 28). Most of the soil moisture requirement was obtained from the 0- to 18-inch depth.

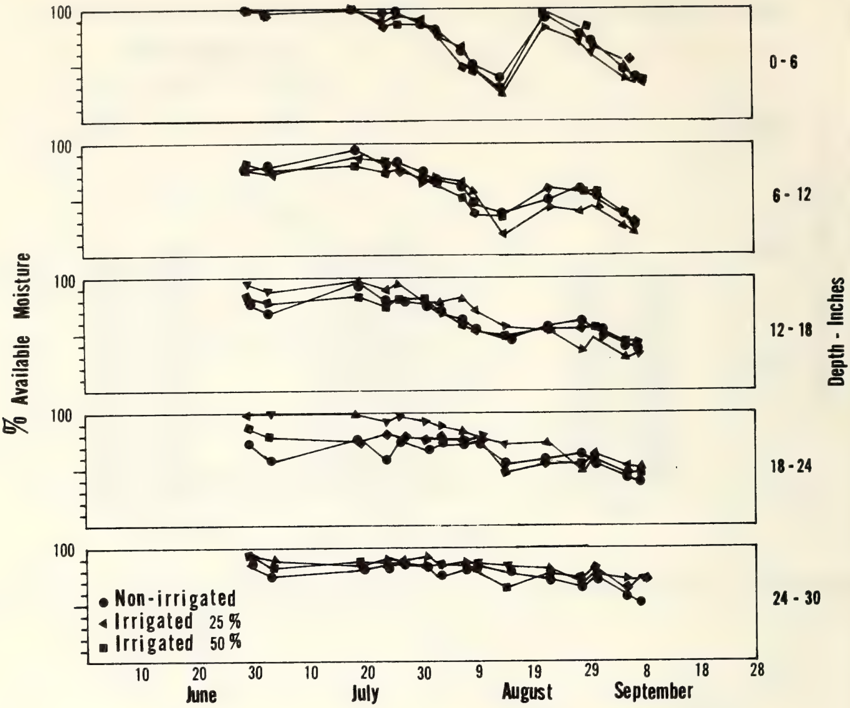

FIGURE 28.—Soil moisture trends for irrigated and non-irrigated cotton from 0- to 30-inch depth, 1961.

Data for 1962

Yield Response: Irrigated cotton yielded 1,337 pounds of seed cotton more per acre than non-irrigated (Fig. 29). There were no significant differences between the 25 percent or 50 percent moisture regimes or among the plant populations. Due to the extremely dry harvesting season there was a minimum of lodging and boll rot.

Rainfall: May was an extremely dry month with a total of .5 inch of rainfall from May 1 through May 28 (Fig. 30). From July 1 through August 24, the most critical time for cotton production, 2 inches of rain was received. During this time the 25 percent moisture regime plots were irrigated July 13, July 27, and August 14. The 50 percent moisture level plots were irrigated July 5, July 13, July 23, August 7, and August 14.

Soil Moisture Trends: Available soil moisture on non-irrigated plots was approaching wilting point at the 0- to 6-inch depth July 12 (Fig. 31). The available soil moisture progressively reached the wilting point to a depth of 30 inches by August 8. Throughout the remainder of the

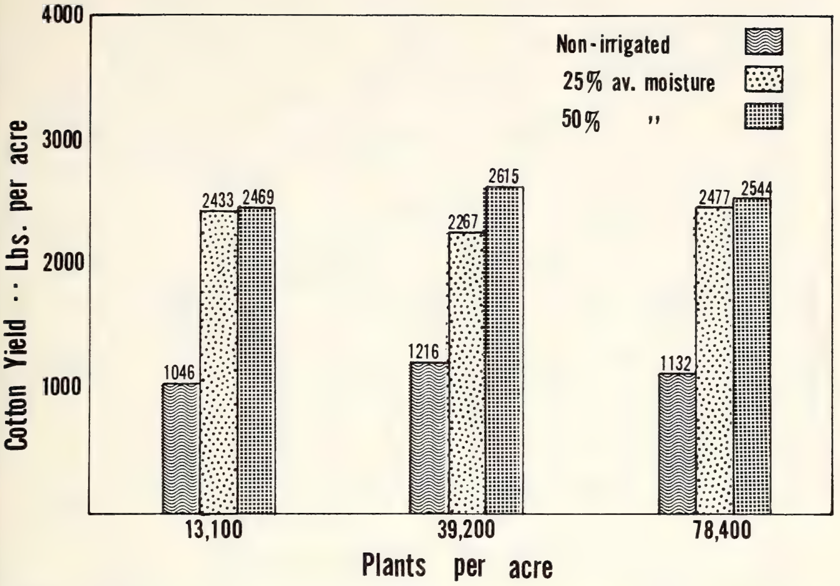

FIGURE 29.—Response of cotton to levels of soil moisture and plant population, 1962.

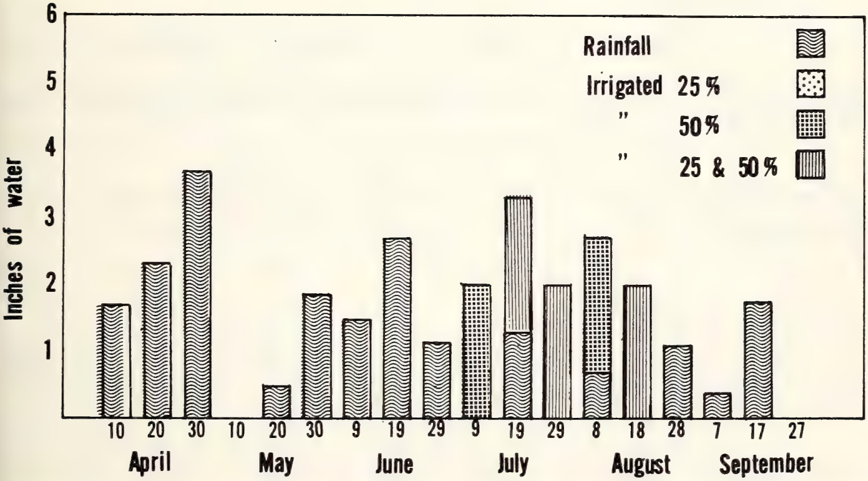

FIGURE 30.—Rainfall distribution by 10-day periods, and irrigation water applied to cotton, 1962.

fruiting season the soil moisture remained at the wilting point to this depth. The plants did not permanently wilt and die; therefore, moisture appeared to be extracted from below the depth of sampling. During the latter half of August the plants under the 25 percent and 50

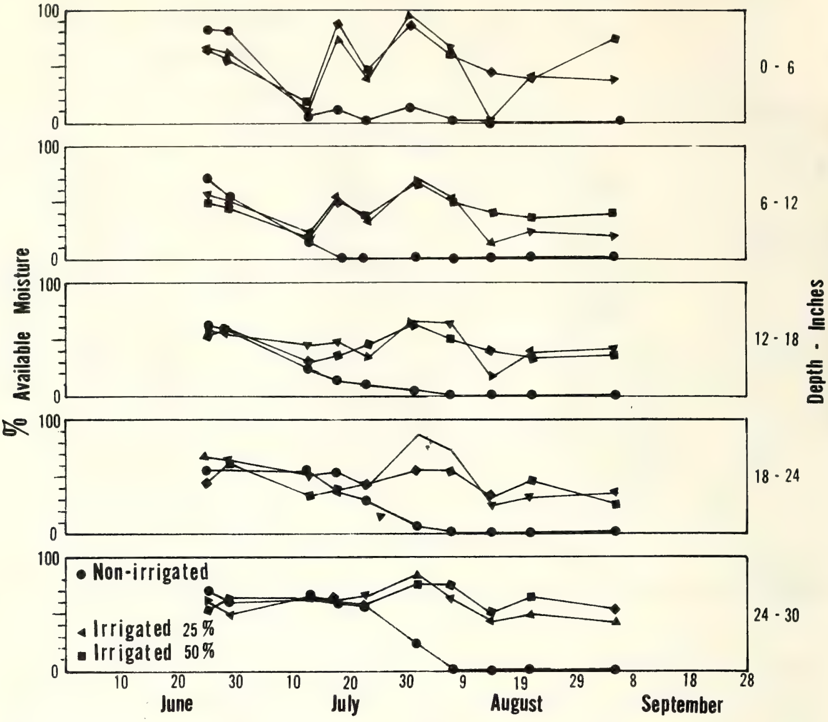

FIGURE 31.—Soil moisture trends for irrigated and non-irrigated cotton from 0- to 30-inch depth, 1962.

percent irrigation regimes were definitely removing moisture to the 24-inch depth.

Summary of Results

Irrigation increased cotton yields in 3 of the 5 years of testing. Yield increases from irrigation ranged from 104 pounds of seed cotton per acre to 1,913 pounds, with an average increase of 823 pounds.

A 5-year average yield of 1,524 pounds of seed cotton has been produced without irrigation, 2,329 pounds where the moisture level was maintained at the 25 percent available soil moisture, and 2,366 pounds where soil moisture was maintained at the 50 percent level (Fig. 32). There were no significant differences in yield between the 25 percent and 50 percent available soil moisture levels in any of the years of testing.

The number of irrigations required to maintain the soil moisture at the 25 percent level ranged from none to three with an average of 1.8

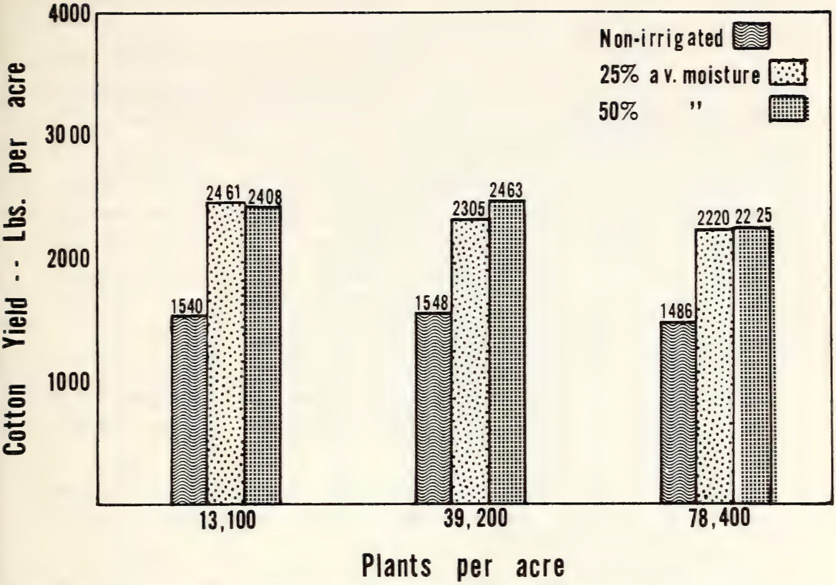

FIGURE 32.—Response of cotton to levels of soil moisture and plant population, five-year average, 1958-62.

irrigations per year. The number required to keep the soil at the 50 percent level ranged from two to five, with an average of 3.2.

Yields for plant populations were significantly different in 2 of the 5 years of testing. These differences were for the years of 1958 and 1960. September of 1958 was extremely wet. Rain fell 13 days with a total amount of 11.9 inches. In August, 1960, rain fell 12 days with a total amount of 10.4 inches. During these 2 years of testing there were significant differences in yield due to population. Under all moisture regimes there was a decrease in yield as the number of plants per hill increased.

From the data it appears that in years having a wet late summer, as plant populations increase there will be a decrease in yield. For the years 1959, 1961, and 1962 there were no differences among the plant populations, which indicates that in years not having an extremely wet late summer population is not a factor in cotton production.

Conclusions

A study has been made to determine the effect of irrigation, fertilization, water regime, and plant population on the yield of cotton and moisture extraction patterns from the soil. Experiments were conducted at the Macon Ridge Branch Experiment Station, Winnsboro, on Richland and Olivier silt loam soil for a 5-year period, 1958 through 1962.

Under the conditions which these experiments were conducted the following conclusions appear to be valid:

1. The response of cotton to irrigation must be evaluated over a period of several years. Yield increases due to supplemental irrigation on Richland silt loam soil ranged from 0 to 1,937 pounds of seed cotton per acre. Average yields at the 120 pound level of nitrogen were 2,602 and 1,852 pounds of seed cotton for irrigated and non-irrigated cotton respectively, with an average increase of 750 pounds of seed cotton per acre from irrigation.
2. Irrigation is made more effective by the use of nitrogen. With irrigation and no nitrogen on Richland silt loam soil the yield increase due to irrigation has ranged from 0 to 1,006 pounds per acre, with an average increase of 273 pounds. At the 120 pound rate of nitrogen the yield of cotton ranged from 100 to 1,937 pounds per acre, with an average increase of 750 pounds per acre.
3. The total rainfall and distribution was found to be extremely critical during the months of July and August. During the 5 years that the "Effect of Irrigation on the Response of Cotton to Fertilization" study was conducted, two irrigations, one in July and one in August, were required in each year 1958, 1959, and 1960. In 1961, irrigation was not required due to total amount and distribution of rainfall. In 1962, four irrigations were required, two each in July and August.
4. Although significant yield increases were obtained from the 120 pound nitrogen rate in 2 of the 5 years of testing, no reduction in yields occurred in the other 3 years. In 1 of the 5 years, 180 pounds of nitrogen reduced cotton yields. The interaction of irrigation and nitrogen rates was significant in 3 of the 5 years of testing.
5. From the data it appears that different nitrogen recommendations can be justified for irrigated and non-irrigated cotton. On Richland silt loam, and for other soils with similar physical and chemical properties, a nitrogen rate between 90 and 120 pounds per acre can be recommended for cotton grown under irrigated conditions and 60 to 80 pounds for non-irrigated cotton.
6. Due to limitations of the experimental design it was impossible to determine if yield increases were obtained by the addition of 60 pounds of phosphorus and/or potassium. There were no increases in yield under irrigated or non-irrigated conditions from the addition of phosphorus and/or potassium above the 60 pound level.
7. It appears that one plant per hill 12 inches apart in the drill on Olivier silt loam soil is equal to or better than the other plant populations studied. High nitrogen levels under irrigated

conditions coupled with a thick plant population and a wet late summer is more conducive to plant lodging and boll rot, thereby reducing cotton yields.

8. Irrigating at approximately the 25 percent available soil moisture level was as effective in increasing yields as irrigating at approximately the 50 percent available soil moisture level. On the average it would require approximately one irrigation more to maintain the soil at the 50 percent moisture level in the Macon Ridge area. Irrigation on Olivier silt loam soils increased yields by 823 pounds of seed cotton per acre.

9. Cotton roots will extract most of their moisture supply from the topsoil in years of ample rainfall. In dry years more of the moisture needs of the cotton plants will be met by extracting water from greater depths, but the amount which can be extracted will be progressively less as depth increases. In very dry years it is obvious that moisture is extracted from below the 24-inch depth, but not enough to maintain optimum growth during the critical period of blooming and boll development.

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Wm. H. Patrick, Jr.
Ronald Wyatt
R. H. Brupbacher

A Study of Chemical and Physical Properties of Three Alluvial Soils in the Sugar Cane Area of Louisiana

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gricultural Experiment Station
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A Study of Chemical and Physical Properties of Three Alluvial Soils in the Sugar Cane Area of Louisiana

WM. H. PATRICK, JR., RONALD WYATT AND R. H. BRUPBACHER
Department of Agronomy

One of the most important areas in which sugar cane is grown in Louisiana is along both sides of Bayou Teche and its distributaries. The area extends through St. Landry, St. Martin, St. Mary and Iberia parishes. Three soil series, Iberia, Cypremort and Baldwin, comprise a large portion of the arable land in this area and occupy almost 250,000 acres. They are classified by Lytle *et al.* (*5*) as Mississippi River Terrace Soils of Late Pleistocene - Early Recent origin.

These soils were formed from the deposits of the Mississippi River and its distributaries when the Mississippi flowed through the channel now occupied by Bayou Teche and which it left about 2,000 years ago (*3*). The soils on the natural levees of the Teche-Mississippi and its two main distributaries, Bayou Sale and Bayou Cypremort, have been developing since that time with no further additions of alluvium.

Among the most striking features of these soils are the physical factors of drainage, structure and texture, which appear to be more important than chemical properties in determining the suitability of the soil for sugar cane production. Their relatively poor subsurface drainage, fine texture, and in some cases artificial compaction, account for the significance placed on physical properties as indices of the productivity of these soils.

The general depositional pattern of these soils is characteristic of the manner in which an overflowing stream deposits its suspended load. Coarser alluvial materials were deposited near the stream channel on the highest elevation of the natural levee ridges along the banks of the stream. The finer sediments, silty clays and clays, were carried in suspension and deposited farther from the channel toward the back swamps. Generally this has resulted in a gradation from fine sands and silts to silty clays and clays as the distance from the stream increased.

Thus the coarsest textured Cypremort soils occupy front lands on the crests of the natural levees adjacent to the stream channel. These soils are moderately well-drained and have been moderately leached of bases. They have been in place long enough to have developed profiles. The Cypremort soils have a brown A horizon that ranges in depth from 6 to 10 inches and a silty clay loam subsoil (*5*). Most areas have been planted to row crops for more than 100 years.

Following the general depositional pattern, the Baldwin soils usually occur at elevations about halfway between the Cypremort soils and the lower lying Iberia soils. They are not so well drained as the Cypremort soils, being imperfectly drained to poorly drained. The A horizon is grayish brown to very dark grayish brown and ranges from 8 to 12 inches in depth (*5*). The subsoil is slowly permeable clay as compared with the moderately permeable silty clay loam subsoil of the Cypremort series.

Iberia soils, which are generally the finest-textured of the three series, are developed from materials of high clay content deposited in the back swamps or slack water areas adjacent to the natural levees. They occur at slightly lower elevations than the associated Cypremort and Baldwin soils and are adjacent to the swamp soils. Both surface and subsurface drainage are poor in these soils because of their low elevation and fine texture. The Iberia soils have a dark gray to black A horizon that varies in depth from 7 to 10 inches (*5*).

Shuker (*9*) made a study of the physical properties of complete profiles of each of these soils and found that their most distinctive feature was the relatively poor internal soil drainage. He concluded that this feature and their fine texture were the two most important physical characteristics determining their suitability for sugar cane production.

The chemical characteristics of six profiles of these soils were studied by Driskell (*2*). Some of his results were published in the Soil Survey Report of St. Mary Parish (*5*). He found the Iberia soils to be higher than the Baldwin and Cypremort soils in organic matter content, exchangeable calcium, pH, exchangeable potassium and total exchange capacity. The Cypremort soils were lowest in organic matter content, total cation exchange capacity, calcium, magnesium, phosphorus and pH.

Because of the importance of soil physical properties in determining the productivity of these soils, a detailed study of certain physical and chemical properties of representative soils of the Cypremort, Baldwin and Iberia series has been made. The relationship of these physical and chemical properties to each other was also examined in this study.

Sampling and Preparation of Samples

For this study 25 samples of the A_p horizon of each soil series were collected from an area of approximately 170 square miles in St. Mary Parish, Louisiana. The sampling sites were chosen on or adjacent to the natural levees of the Bayou Teche, having been preselected by using the Soil Survey of St. Mary Parish made by Lytle *et al.* (*5*). Each sample was composed of about 10 subsamples collected in a small area in fields either supporting a cane crop or lying in summer fallow between cane crops. Representative samples of each series were collected.

After thorough mixing, the samples were gently crushed by hand to pass through a sieve with 8 mm. openings and then allowed to air dry. The 8 mm. soil was used for water-stable aggregate determination, particle size analysis and moisture determination. A portion of the soil was passed through a 2 mm. sieve for 1/3- and 15-atmosphere moisture percentages. Subsamples of the air-dry 8 mm. soil were crushed to pass a 35 mesh screen for other analyses.

Laboratory Analyses

Water-stable aggregates were determined by the wet-sieving method as outlined by Van Bavel (*11*). After testing for the presence of carbonate carbon with hydrochloric acid, organic carbon was determined in a dry combustion chain as suggested by Piper (*8*), and converted to organic matter by the factor 1.724. Duplicate 40 gram samples of 8 mm. air-dried soil were used to determine the percentages of sand, silt and clay by the proposed hydrometer method of the Committee on Physical Analyses of the Soil Science of America (*1*) as modified by Patrick (*7*).

The field capacity and wilting point of the soils were estimated by measuring 1/3- and 15-atmosphere moisture percentages, respectively. One-third-atmosphere moisture percentage was determined by using a porous plate assembly and 15-atmosphere moisture percentage determined with a pressure membrane assembly.

Total cation exchange capacity, reported in milliequivalents per 100 grams of dry soil, was determined by leaching the soil with 1N ammonium acetate and using the method adopted by Hanes (*4*). pH determinations were made with a Beckman glass electrode pH meter on a 1:1 soil-water mixture that had been allowed to stand for 24 hours.

Exchangeable calcium, magnesium and potassium were all extracted at a 1:20 soil-to-solution ratio by shaking the soil for 15 minutes with .1N hydrochloric acid solution. The concentrations of calcium and potassium were determined by use of a Perkin-Elmer flame photometer, using lithium as an internal standard. Magnesium was determined by the Clayton Yellow colorimetric method (*6*). The calculation of base saturation was made by using the values of extractable calcium, magnesium and potassium. Phosphorus was extracted with .1N hydrochloric acid and .03 N ammonium fluoride solution at a 1:20 soil-to-solution ratio and determined colorimetrically with a Bausch and Lomb Spectrophotometer.

Results and Discussion

Results of the chemical and physical analyses are presented in Tables 1, 2 and 3.

The means of these results for each soil series are shown in Figures 1 and 2.

Simple correlation coefficients for all properties studied are shown in Table 4.

Percent Clay.—Clay contents of the A horizon of the 75 samples of the three soil series were found to vary from 10.1 to 58.8 percent. Due

TABLE 1.—Physical and chemical properties of the A_p Horizon of Cypremort soils

Sample No.	Field Classi-fication*	% Agg. .21 mm.	Clay %	O.M. %	C.E.C. m.e. per 100 g. soil	Base Sat. %	Ca ppm.	Mg ppm.	pH	P ppm.	K ppm.	1/3-Atm.	15-Atm.
1	vfsl	28.4	20.0	1.83	11.81	84.9	1,515	277	5.7	49	82	23.52	8.45
2	sil	28.6	18.2	1.70	11.00	90.6	1,470	305	5.6	70	52	25.54	7.44
3	vfsl	49.7	15.3	2.29	10.78	83.7	1,425	210	5.5	103	65	23.96	7.16
4	sil	25.4	20.5	1.52	11.73	60.0	905	285	4.8	28	65	25.01	8.06
5	sil	21.4	24.5	1.64	12.23	56.1	865	285	4.8	18	82	25.72	9.25
6	vfsl	15.5	19.7	1.52	11.45	100+	1,945	272	6.5	75	48	23.56	7.66
7	vfsl	14.2	22.1	1.12	12.26	77.2	1,380	285	5.8	31	91	23.31	8.61
8	vfsl	19.7	27.1	1.29	14.92	47.9	865	299	4.8	39	143	26.29	10.35
9	sil	23.1	31.8	1.90	16.32	63.2	1,295	430	5.2	29	117	29.63	11.53
10	sil	17.9	15.5	1.36	9.78	83.5	1,210	245	5.9	64	48	21.25	6.33
11	vfsl	23.1	20.4	1.35	12.14	100+	2,030	422	7.1	70	39	22.42	7.70
12	vfsl	26.1	19.7	2.24	13.94	98.3	2,073	387	6.5	178	65	25.88	8.13
13	vfsl	13.5	14.5	1.10	9.55	74.2	950	257	5.6	28	95	18.48	5.94
14	sil	16.7	20.5	1.36	12.85	75.6	1,255	380	5.9	39	134	23.43	8.17
15	vfsl	9.7	14.5	1.09	9.34	69.9	905	225	5.6	19	60	18.13	5.78
16	vfsl	21.3	21.0	1.76	14.02	88.2	1,730	430	6.3	33	78	24.16	9.14
17	sil	20.1	15.3	1.42	10.12	81.2	1,210	251	5.6	356	52	17.21	6.06
18	vfsl	15.1	18.4	1.22	11.28	94.0	1,510	358	6.3	50	52	19.52	6.96
19	vfsl	24.4	29.8	1.45	16.54	73.0	1,555	486	5.2	67	125	25.72	11.50
20	vfsl	41.3	20.5	1.85	11.78	100+	3,990	231	7.5	42	82	21.37	7.52
21	vfsl	13.2	10.1	0.76	6.47	80.2	735	165	5.7	21	65	13.17	4.14
22	vfsl	21.9	23.6	1.20	13.79	76.5	1,425	387	5.9	145	99	25.25	9.61
23	vfsl	18.9	19.7	1.36	11.02	79.1	1,210	305	5.9	28	65	21.61	7.61
24	vfsl	18.2	21.7	1.13	11.59	75.5	1,165	336	5.3	28	65	21.24	8.18
25	sil	18.6	19.1	1.31	11.16	57.1	820	263	5.4	18	43	21.43	7.58
Average	. . .	21.83	20.13	1.471	11.91	78.80	1,418	311	5.78	65.1	76.5	22.67	7.95

*As determined by Lytle, *et al.* (*5*).

TABLE 2.—Physical and chemical properties of the A_p horizon of Baldwin soils

Sample No.	Field Classi-fication*	% Agg. .21 mm.	Clay %	O.M. %	C.E.C. m.e. per 100 g. soil	Base Sat. %	Ca ppm.	Mg ppm.	pH	P ppm.	K ppm.	1/3-Atm.	15-Atm.
1	sic	68.7	33.7	3.23	23.20	85.2	2,940	574	6.5	61	147	31.57	15.42
2	sil	25.0	15.4	1.73	12.10	85.4	1,555	299	5.5	70	43	19.73	7.31
3	sil	46.6	21.5	3.20	16.49	86.8	2,160	405	6.0	117	78	27.70	11.11
4	sicl	32.9	32.7	2.34	19.72	63.2	1,730	440	5.0	28	86	30.65	12.88
5	sic	34.9	32.9	2.19	21.60	82.3	2,420	666	6.2	15	86	28.04	13.51
6	sicl	20.8	31.4	2.42	19.87	66.5	1,730	528	5.2	42	99	29.83	12.38
7	sil	24.8	27.2	2.20	18.05	63.5	1,510	440	5.0	29	117	28.71	11.28
8	sil	29.3	23.7	1.90	16.42	85.2	1,860	550	5.5	47	78	25.98	10.44
9	sic	29.7	36.9	2.95	24.53	76.1	2,550	686	5.5	53	117	31.46	14.63
10	sicl	43.4	37.1	2.77	27.25	85.6	3,500	686	6.1	254	86	31.57	16.23
11	sic	24.9	31.5	2.50	21.69	75.9	2,205	630	5.3	33	117	31.93	13.77
12	sicl	31.8	32.9	2.57	23.19	81.0	2,550	710	5.4	53	86	29.72	13.82
13	sil	26.2	26.2	2.96	19.42	89.8	2,550	540	6.0	64	104	28.40	11.11
14	sic	24.2	32.0	1.93	20.74	78.3	2,205	594	6.0	183	143	30.41	13.36
15	vfsl	14.7	12.2	1.44	9.88	100	1,510	270	6.7	31	52	18.07	6.57
16	sicl	26.7	31.3	1.91	18.68	78.2	2,030	506	5.8	108	125	29.60	12.76
17	vfsl	20.1	10.2	1.27	8.81	100+	1,380	256	6.7	36	48	18.90	5.69
18	sil	24.4	28.9	1.24	17.95	78.7	1,730	640	5.9	103	99	27.49	12.01
19	sil	23.0	23.8	1.86	16.33	84.8	1,945	480	5.8	39	73	27.60	9.80
20	sicl	24.5	35.3	2.06	19.04	49.4	1,080	440	4.8	22	151	29.63	13.49
21	sic	54.5	46.0	2.81	30.11	70.5	2,850	804	5.7	29	147	35.25	10.97
22	vfsl	29.9	16.4	1.92	11.96	83.9	1,425	336	5.3	49	60	21.93	7.20
23	sic	25.2	31.4	2.36	21.70	83.8	2,635	570	6.1	349	134	30.49	13.23
24	sil	28.6	21.4	2.44	19.15	100+	3,715	387	7.5	92	69	25.49	10.14
25	vfsl	23.0	21.5	1.68	16.38	89.7	2,075	506	6.3	58	73	26.49	10.36
Average	. . .	30.30	27.74	2.234	18.97	80.95	2,153	518	5.83	78.6	96.7	27.87	11.58

*As determined by Lytle, *et al.* (5) .

TABLE 3.—Physical and chemical properties of the A_p horizon of Iberia soils

Sample No.	Field Classi-fication*	% Agg. .21 mm.	Clay %	O.M. %	C.E.C. m.e. per 100 g. soil	Base Sat. %	Ca ppm.	Mg ppm.	pH	P ppm.	K ppm.	1/3-Atm.	15-Atm.
1	sicl	31.9	20.9	1.63	16.99	91.1	2,420	396	6.5	103	60	30.40	9.19
2	sicl	44.3	27.0	3.08	20.26	86.1	2,810	387	5.8	156	99	29.86	11.64
3	c	41.0	30.1	3.81	21.07	90.8	2,940	506	6.2	267	125	31.40	12.33
4	c	37.9	38.7	3.14	24.51	78.7	2,635	722	5.6	26	78	35.03	14.66
5	c	58.2	50.7	3.23	27.92	74.4	2,850	746	5.6	53	164	37.80	19.19
6	c	29.1	32.3	3.03	22.56	82.9	2,680	620	6.0	47	99	33.16	13.57
7	c	27.3	28.8	2.80	19.93	81.3	2,290	552	5.8	56	91	33.45	11.18
8	c	73.4	49.8	3.62	30.42	88.7	3,975	870	6.2	97	117	33.55	16.99
9	c	49.5	44.2	3.16	26.81	83.0	3,025	836	6.0	36	104	33.18	15.67
10	sicl	25.3	32.7	2.70	20.21	75.4	2,075	574	5.2	39	65	31.86	12.10
11	sicl	27.2	30.3	2.67	21.21	94.7	3,025	586	6.5	260	69	30.03	12.47
12	sicl	27.2	17.1	1.76	14.02	99.9	1,985	486	6.5	56	30	27.87	8.12
13	sicl	17.4	24.4	2.17	18.20	93.0	2,375	596	6.5	108	65	28.61	10.64
14	sil	20.0	23.1	2.30	16.90	85.0	2,160	420	5.7	61	52	29.43	9.41
15	c	76.0	57.5	3.94	36.08	87.3	4,145	1270	6.7	150	138	37.91	22.14
16	c	31.0	33.6	3.66	24.24	92.9	3,285	710	6.3	156	117	33.44	14.16
17	sicl	19.2	24.5	2.34	18.94	90.1	2,375	610	6.3	46	73	29.21	10.56
18	c	74.8	58.8	3.89	37.60	88.4	4,760	1112	6.5	19	138	38.42	24.03
19	sil	26.7	27.1	3.17	22.94	91.3	3,065	664	6.1	50	69	31.21	11.65
20	sicl	32.3	30.2	2.62	20.49	76.6	2,115	596	5.5	29	91	31.40	12.23
21	sicl	29.4	33.1	2.38	20.86	85.2	2,420	664	6.0	32	99	33.54	13.75
22	c	43.3	43.2	3.23	28.89	66.9	2,550	756	5.2	44	151	36.27	17.82
23	sil	44.1	27.5	3.75	20.06	90.7	2,680	552	6.1	195	117	33.39	12.07
24	sil	29.6	21.1	2.17	17.36	86.4	2,205	472	6.1	50	48	30.87	10.82
25	c	24.5	31.1	2.85	22.65	83.1	2,720	620	5.8	64	60	31.69	12.31
Average	. . .	37.62	33.52	2.924	22.84	85.76	2,782	653	6.03	88.0	92.8	32.52	13.54

*As determined by Lytle, *et al.* (5).

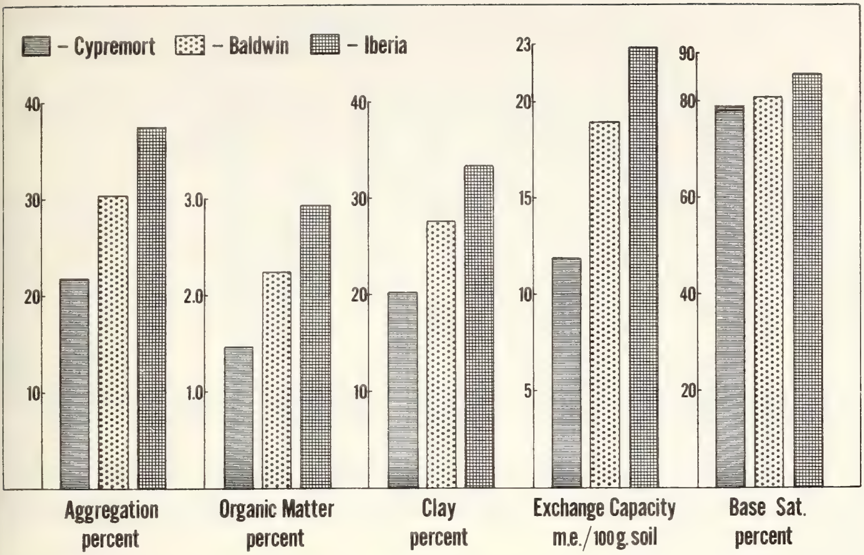

FIGURE 1.—Average values for certain chemical and physical properties of Cypremort, Baldwin and Iberia soils.

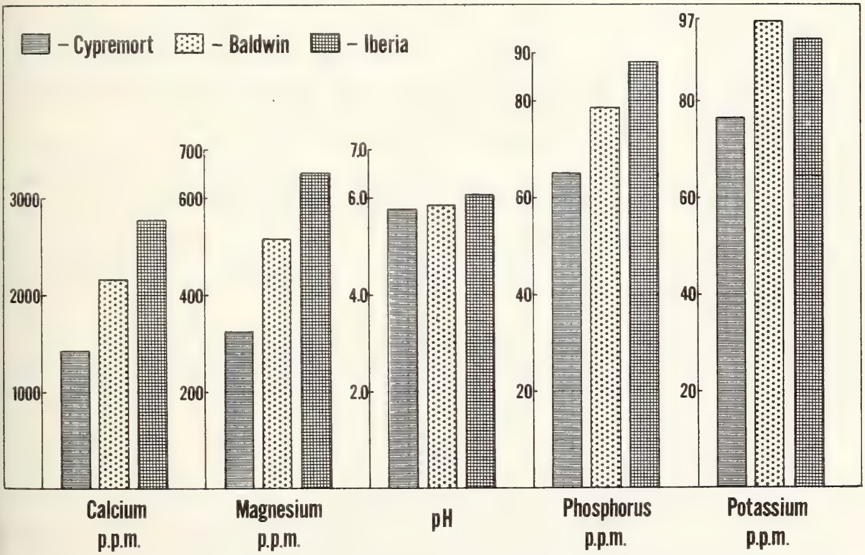

FIGURE 2.—Average values for certain extractable nutrients in Cypremort, Baldwin and Iberia series.

to their proximity to the stream channel, the coarser textured Cypremort soils contained the lowest amount of clay in the A_p horizon, the average for the series being 20.1 percent. The Iberia soils, farthest from the stream channel and developed from the finer materials deposited in the

TABLE 4.—Simple correlation coefficient (r) among physical and chemical properties of the A_p horizon of the Cypremort, Baldwin and Iberia soils

	O.M.	Clay	⅓-Atm.	15-Atm.	C.E.C.	Base Sat.	Ca	pH	Mg	P	K
Agg.	.760	.735	.648	.759	.748	.122	.731	.195			
O.M.		.744	.837	.788	.850	.163	.802	.139			
Clay			.867	.976	.948	.196	.682	.059			
⅓-Atm					.911	−.075	.692	−.026	.847	.104	.595
15-Atm.					.975	−.126	.728	.000	.926	.090	.713
C.E.C.						.015	.808	.081	.949	.140	.630
Base Sat.							.472	.857	.073	.297	.407
Ca								.561	.758	.275	.333
pH									.140	.256	.211
Mg										.093	.535
P											.098

Correlation coefficient required for significance at 1% level of probability = .302

slack water areas, were highest in clay content with an average of 33.5 percent. The intermediately-situated Baldwin soils contained an average of 27.7 percent clay.

Percent Organic Matter.—Organic matter content of these surface soils ranged from 0.75 to 3.94 percent. The lighter colored, coarser textured Cypremort soils were found to be lowest in organic matter, containing an average of 1.47 percent. The darker colored, heavier textured Baldwin soils contained an average of 2.23 percent organic matter. The very dark colored and poorly drained Iberia soils were highest in organic matter content with an average of 2.92 percent for the series.

Figure 3 shows that organic matter was closely related to clay content. The curvilinear regression line in this figure indicates that the organic matter content increased significantly with an increase in clay content. Factors such as cropping systems and soil management are also important in determining the organic matter level of a soil. The soils included in this study, however, had all been subjected to somewhat similar management practices since they were all either in sugar cane or in summer fallow between crops of sugar cane. For this reason clay content appeared to be more important in determining the organic matter content of the soil than any other factors.

Aggregation.—Aggregation is reported as percent water stable aggregates greater than 0.21 mm. The Cypremort soils with the lowest organic matter and clay contents were lowest in percent aggregation, with an average of 21.8 percent for the series. The Baldwin soils, intermediate in clay and organic matter contents, had an average of 30.3 percent aggregation, while the heavy textured Iberia soils, highest in clay and organic matter contents had the highest percent aggregation, averaging 37.6 percent. Higher values of aggregation in the Iberia and Baldwin soils do not mean that these soils have a better structure than the Cypremort soil. On the contrary, soil structure is more critical in the

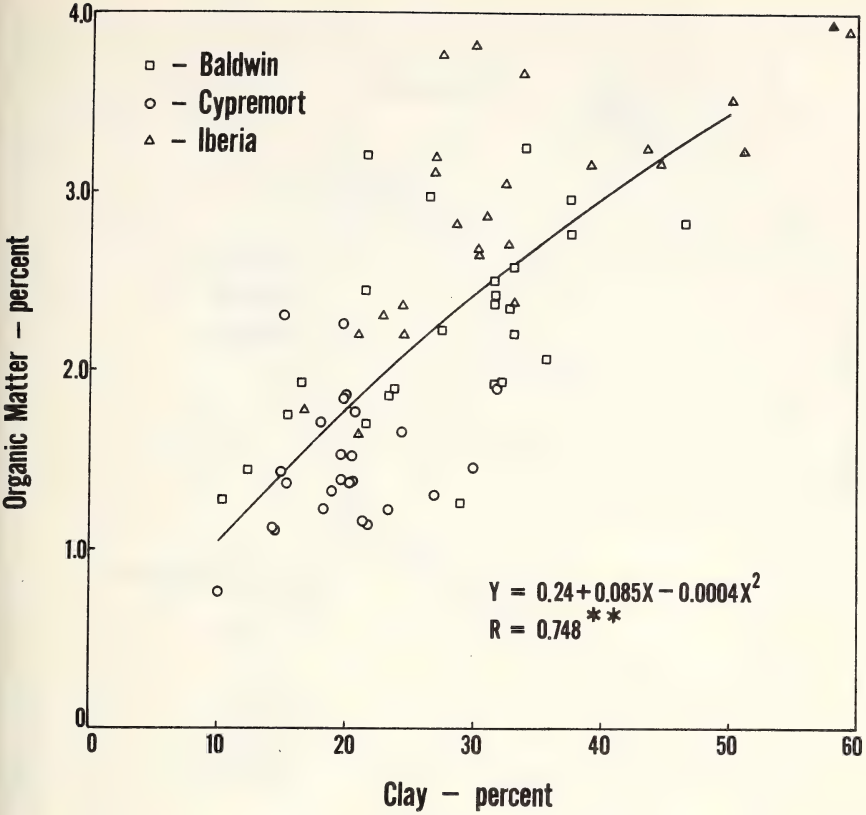

FIGURE 3.—Relationship between organic matter and clay.

Iberia and Baldwin soils as a result of their high clay contents. These soils are much harder to manage than the coarser textured Cypremort soil.

One-Third- and Fifteen -Atmosphere Moisture Percentages.—For the three series 1/3- and 15-atmosphere moisture percentages followed the same trend as organic matter, clay content and aggregation. Both moisture values were highest for the Iberia series and lowest for the Cypremort series.

One-third- and 15-atmosphere moisture percentages were closely related to clay content, as may be seen in Table 4 and Figure 4. The equations relating 1/3- and 15-atmosphere moisture percentages to clay content were:

$$Y_1 = 6.98 + 1.04X - 0.0091X^2$$

$$Y_2 = 0.85 + 0.389X - 0.00033X^2$$

where Y_1 = 1/3-atmosphere percentage
Y_2 = 15-atmosphere percentage
X = percent clay

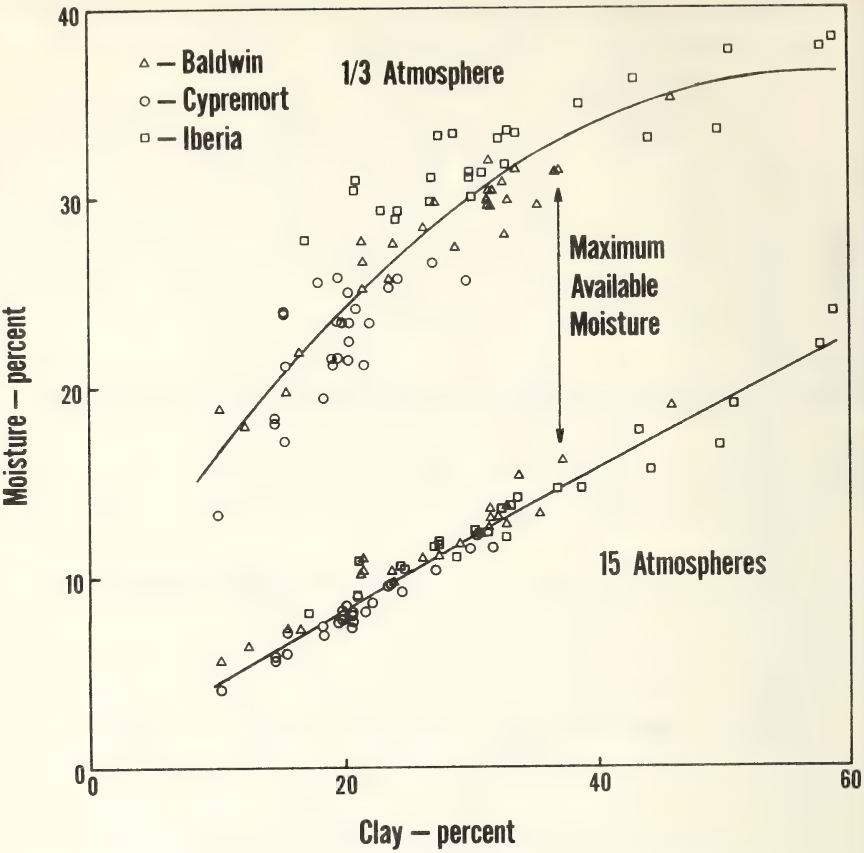

FIGURE 4.—Effect of clay content on ⅓-atmosphere moisture percentage, 15-atmosphere moisture percentage, and available moisture storage capacity.

Fifteen-atmosphere moisture percentage was a near straight-line function of percent clay, while the equation relating 1/3-atmosphere moisture percentage and clay was definitely curvilinear. The difference between the 1/3- and 15-atmosphere moisture percentages is an estimate of the available water-holding capacity of the soil. Available water-holding capacity as a function of clay content was calculated by subtracting the equation for 15-atmosphere moisture percentage from the equation for 1/3-atmosphere moisture percentage. This resulted in the following equation:

$$Y_1 - Y_2 = 6.13 + 0.651X - 0.0088X^2$$

where $Y_1 - Y_2 =$ percent available water

Because of the curvilinear nature of the equation relating available water-holding capacity to percent clay, the clay content at which water-holding capacity was a maximum could be calculated. This calculation showed that a maximum available water-holding capacity of 20.3 percent occurred at a clay content of 37.1 percent.

Cation Exchange Capacity.—The average values of cation exchange capacity for the three soil series were 11.91 m.e./100 g. for the Cypremort, 18.97 m.e./100 g. for the Baldwin and 22.84 m.e./100 g. for the Iberia. Cation exchange capacity was closely related to both organic matter and clay content as may be seen in Figures 5 and 6. A multiple regression equation relating cation exchange capacity to both organic matter content and clay content was calculated. This equation had the form:

$$Y = 0.02 + 0.45X_1 + 2.60X_2$$

where Y = cation exchange capacity
X_1 = percent clay
X_2 = percent organic matter

This equation had a multiple correlation coefficient of 0.973. This

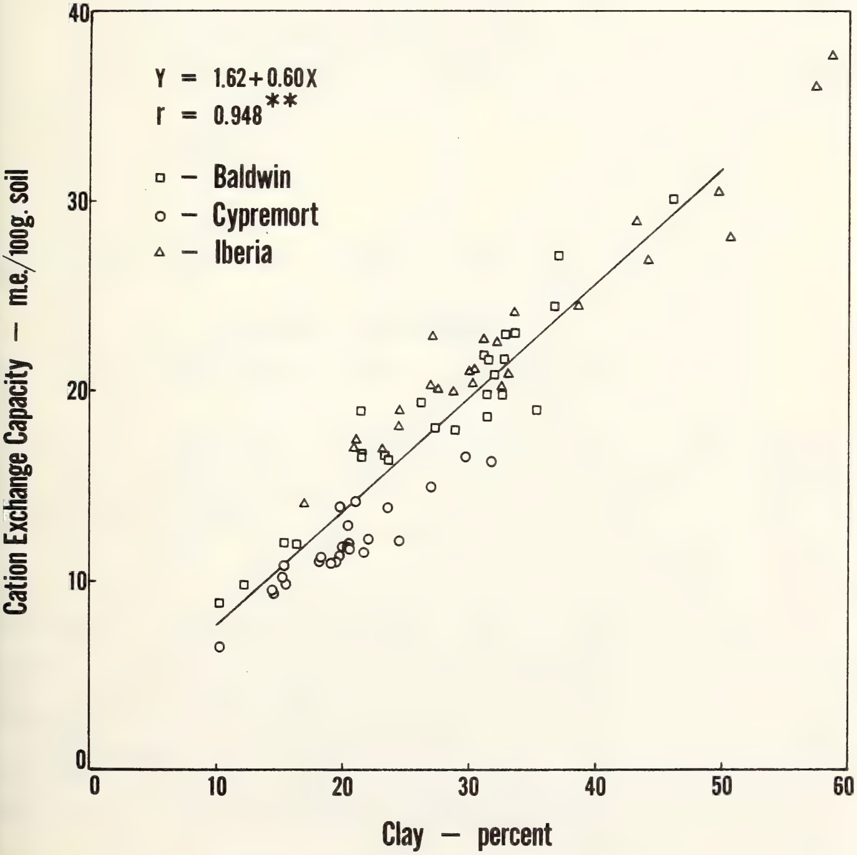

FIGURE 5.—Relationship of cation exchange capacity to clay.

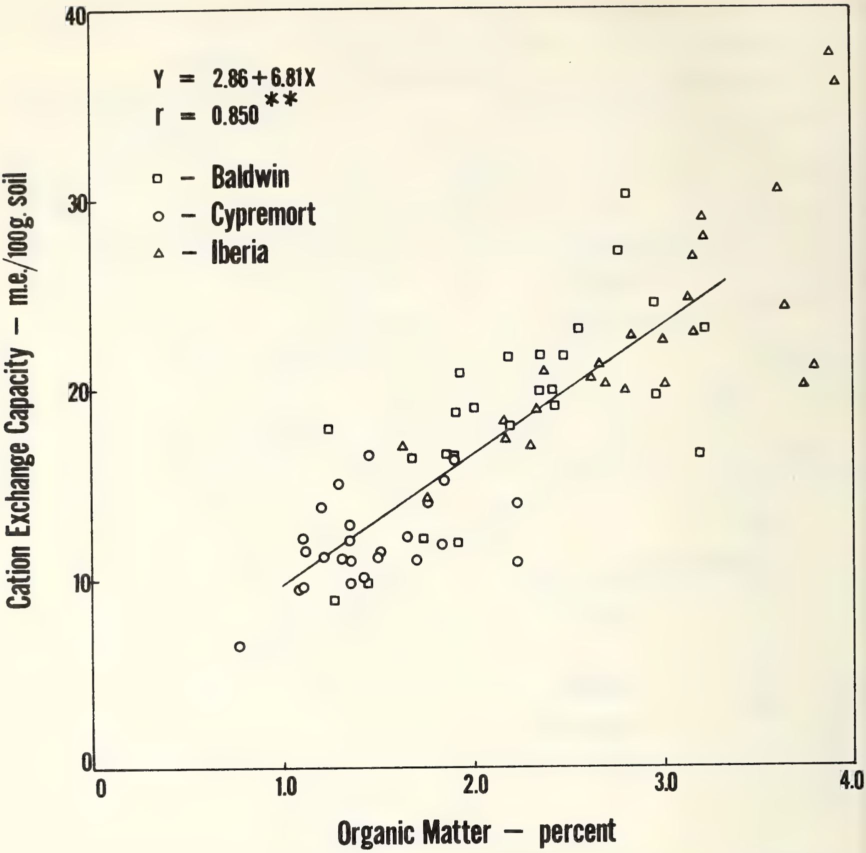

FIGURE 6.—Relationship of cation exchange capacity to organic matter.

shows that approximately 95 per cent of the variation in cation exchange capacity could be accounted for by changes in organic matter and clay content. A fairly accurate estimate of the cation exchange capacity of one of these soils could thus be made from a knowledge of its clay content and organic matter content.

Percent Base Saturation.—The base saturation for individual soils ranged from 47.1 percent to 100 percent. Approximately three-fourths of the soils were between 75 and 95 percent base saturated. Most of the soils with low values for percent base saturation belonged to the moderately well-drained Cypremort series. The average base saturation values of the three series were 78.8 percent for the Cypremort series, 81.0 percent for the Baldwin series, and 85.8 percent for the Iberia series. It is likely that the Cypremort and Baldwin soils that had a base saturation of 100 percent had been limed.

The results for percent base saturation indicate that these soils have been only moderately leached of bases. Their fairly high base saturation attests to their relative youth. Nearby Pleistocene Terrace soils which have been weathering in place long enough to have well developed profiles have a base saturation of about 50 percent in the surface soil.

pH.—The range in pH for the soils was found to be from 4.8 to 7.5. For the Cypremort soils the average pH was 5.78, for the Baldwin soils 5.83, and for the Iberia soils 6.03. There was a close relationship between pH and percent base saturation as is shown in Figure 7. Percent base saturation could be estimated fairly accurately from the pH value for these soils.

Calcium.—The range in extractable calcium content for the 75 soil samples was 820 to 4,760 ppm. The average for the Cypremort soils was found to be 1,418 ppm., for the Baldwin soils 2,153 ppm. and for the Iberia soils 2,782 ppm. High calcium content and a high pH in several

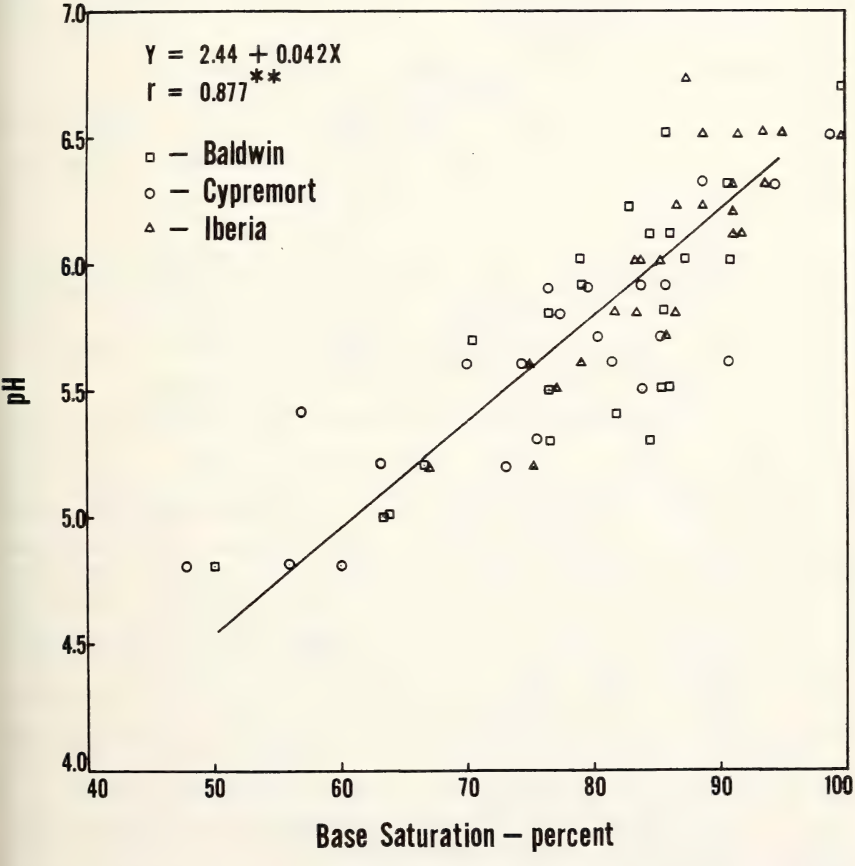

FIGURE 7.—Relationship between pH and base saturation.

of the Cypremort soils suggest that lime had been applied to these soils.

Magnesium.—The range in extractable magnesium was found to be from 165 to 1,270 ppm. Averages of 211, 518 and 653 ppm. were measured for the Cypremort, Baldwin and Iberia soils, respectively. Magnesium was found to be very closely related to cation exchange capacity and calcium; this element was highest in the Iberia soils, and lowest in the Cypremort soils. These soils have an adequate supply of magnesium for proper plant growth. Byrnside and Sturgis (*10*) found no response of sugar cane to magnesium fertilization.

Phosphorus.—Extractable phosphorus varied from 15 to 356 ppm. The wide range in phosphorus content reflects heavy additions of phosphorus to some of the soils in addition to the normal variation in phosphorus content. Phosphorus was lowest in the Cypremort soils with an average of 65.1 ppm., intermediate in the Baldwin soils with an average of 78.6 ppm. and highest in the Iberia soils with an average of 88.0 ppm. These soils vary in their response to phosphorus fertilization; generally where extractable phosphorus is low, significant response to phosphorus fertilization is achieved.

Potassium.—The range in available potassium was found to be 30 to 164 ppm. It was found to be lowest in the Cypremort soils with an average of 76.5 ppm., highest in the Baldwin soils with an average of 96.7 ppm., and intermediate in the Iberia soils with an average of 92.8 ppm. These soils have been found to vary in their response to potassium fertilizers. Generally, where potassium is low, 40 to 60 lbs. of K_2O have been found to be beneficial; above these levels no response has been obtained. The Iberia soils tend to respond better to potash fertilizer than do the Baldwin soils. The Baldwin soils were intermediate between the Cypremort and Iberia soils in most of the properties studied, but were higher than the Iberia soils in extractable potassium.

Relation of Aggregation to Organic Matter and Clay.—The relationships between aggregation and organic matter content and between aggregation and clay content are shown in Figures 8 and 9. Statistical analyses revealed that both these relationships were significant at the 1 percent level of probability. The analyses did not reveal, however, which of the two variables, organic matter or clay, had the most effect on aggregation. An attempt was made to separate these effects by statistical means. It seemed probable that aggregation might actually be related to only one of the factors, organic matter or clay, and appear to be correlated with the other variable, due to a close relationship between organic matter and clay. To study the effect of organic matter on aggregation independent of clay content, the correlation between aggregation and organic matter was measured while clay was held at a fairly constant level. This was achieved by selecting and statistically analyzing two groups of samples in which organic matter covered a moderately wide range while clay varied only slightly. Sixteen samples

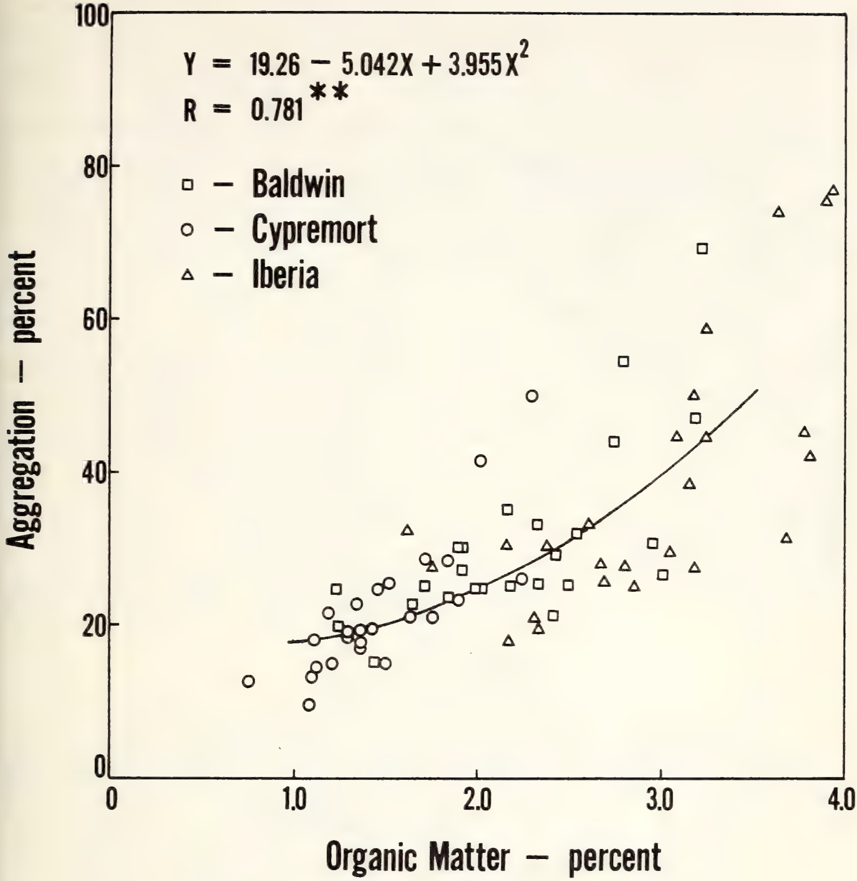

FIGURE 8.—Relationship of aggregation to organic matter.

were chosen in a low clay range in which clay varied only from 19 to 22 percent and 12 samples were chosen in a higher clay range with a small variation of clay content from 31 to 33 percent. The results of this statistical analysis are shown in Table 5. The correlation coefficient between aggregation and organic matter at a relatively low and nearly constant clay level was highly significant, but at a relatively high clay level the correlation was nonsignificant. Thus, organic matter appeared to be more effective in promoting aggregation at a low clay content than at a high clay content. At the high clay level, any effect of organic matter on aggregation appeared to be masked by clay.

The relationship of aggregation to clay content independent of organic matter was studied in a similar manner and the results are tabulated in Table 5. A nonsignificant correlation between aggregation and clay was found at both levels of organic matter selected, although the correlation was considerably higher at the low organic matter level than at the high organic matter level.

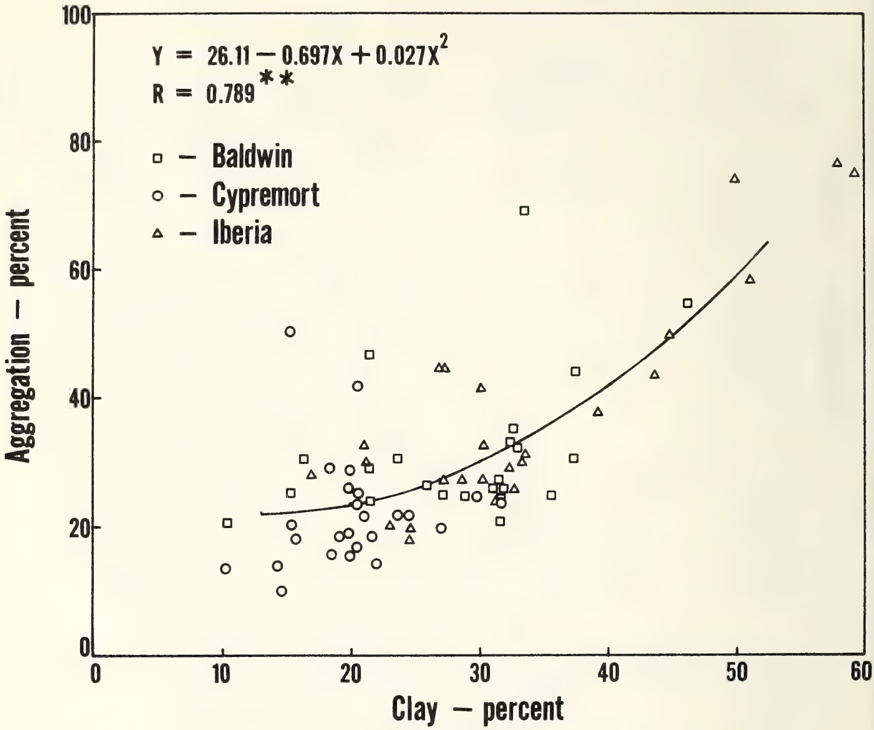

FIGURE 9.—Relationship of aggregation to clay.

TABLE 5.—Simple correlation coefficient (r) between aggregation and organic matter at two levels of clay, and between aggregation and clay at two levels of organic matter

n	Y	X	r
16	Agg.	O.M. (Clay 19-22%)	.772**
12	Agg.	O.M. (Clay 31-33%)	.096
13	Agg.	Clay (O.M. 1.1-1.4%)	.430
11	Agg.	Clay (O.M. 2.1-2.4%)	.191

**Significant at 1% level of probability.

Summary and Conclusions

A study was made of certain physical and chemical properties of the A_p horizon of three important soil series of alluvial origin in the sugar cane area of Louisiana. These soils occur on the natural levees of the channel now occupied by Bayou Teche in South Louisiana.

The better drained Cypremort soils, occurring at the highest elevations and closest to the stream channel, had the coarsest texture, lowest organic matter content and the lowest aggregation. They also contained the lowest levels of mineral nutrients. The very poorly drained and fine-textured Iberia soils, occurring farthest from the channel at the lowest elevations was highest in organic matter, percent aggregation and content of mineral nutrients. The Baldwin soils, generally lying between the Cypremort and Iberia soils, were intermediate in physical properties and extractable nutrients. An exception to this pattern was extractable potassium which was slightly higher in the Baldwin soils than in the Iberia soils.

The interrelations of the various physical and chemical properties were also studied. One-third- and 15-atmosphere moisture percentages were closely related to clay content. A maximum available water-holding capacity of 20.3 percent occurred at a clay content of 37.1 percent. Ninety-five percent of the variation in cation exchange capacity in these soils could be accounted for by variations in organic matter content and clay content. It was found that aggregation was also closely related to both organic matter and clay in these soils. Because of the close association between organic matter and clay, it was difficult to measure their separate effects on aggregation.

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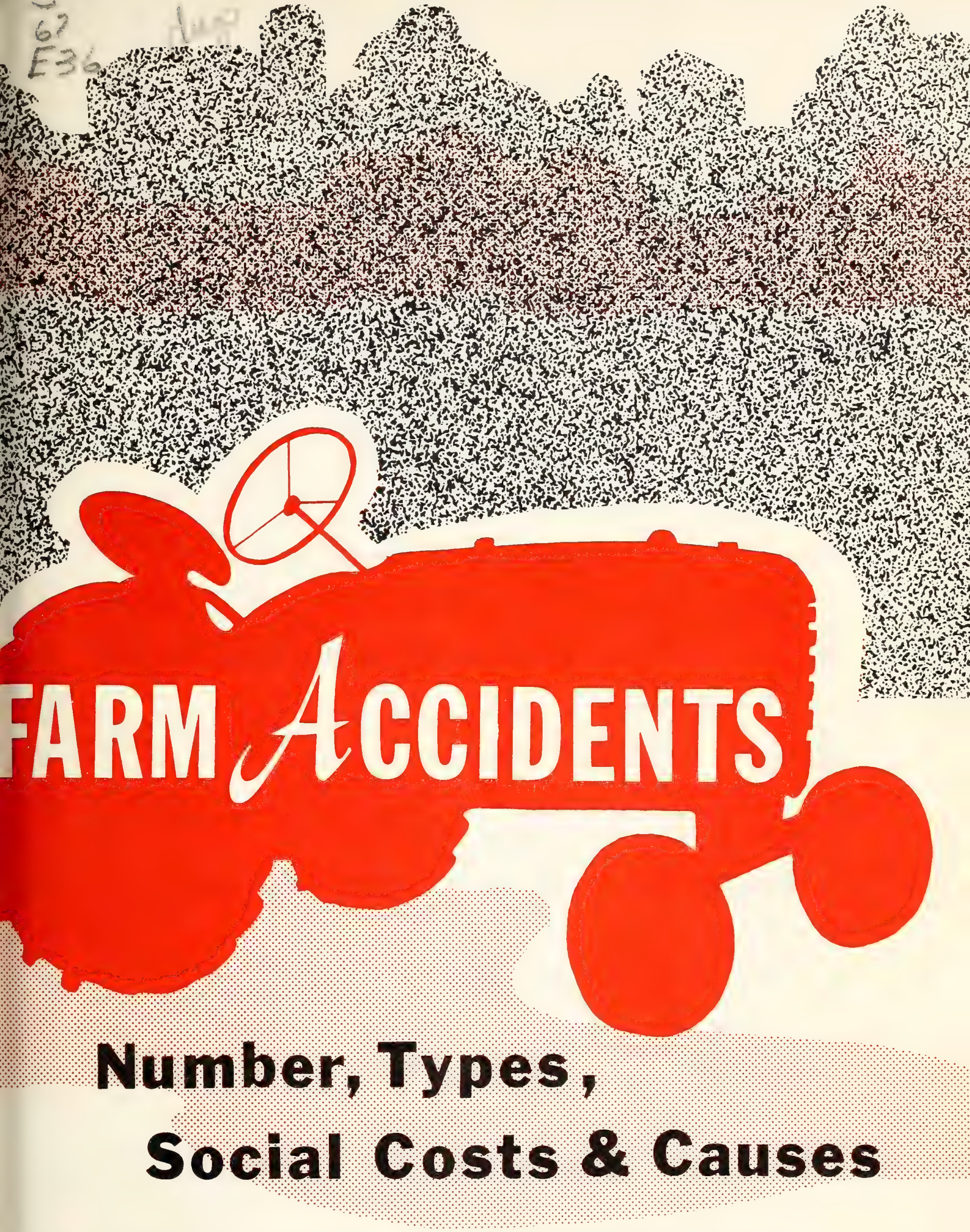

FARM ACCIDENTS

Number, Types, Social Costs & Causes

By Alvin L. Bertrand

Louisiana State University and
Agricultural and Mechanical College
Agricultural Experiment Station
Charles W. Upp, Director

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Summary

The data used in this study were obtained from three sources: The National Health Survey, a field survey conducted in sample areas of the state, and statistics compiled by the State Department of Health. Analysis of these data determined that:

(1) Approximately 255 persons are injured annually per 1,000 population in the United States. This rate amounts to some 45 million persons per year.

(2) Rural-nonfarm residents have the highest accident injury rate (267 per 1,000 population) when compared to urban residents (253 per 1,000 population) and rural-farm residents (241 per 1,000 population). About 80 per cent of the injuries among rural-nonfarm and urban residents are sustained by males.

(3) Approximately nine million persons currently employed sustain work injuries annually in the United States. Thus eight out of ten injuries in the nation occur in non-work situations.

(4) Rural-farm persons have by far the highest annual rate of accidental injury while on the job, 17 annually per 100 currently employed persons. In both urban and rural-nonfarm residence groups, approximately 13 persons per 100 are injured annually while at work.

(5) Of the 255 persons per 1,000 population injured annually in the United States, 27 are injured in motor vehicle accidents, 46 in work accidents, 107 in home accidents, and 75 in miscellaneous accidents. The high rate of home accidents is attributed to the fact that children, youths, and persons over 65 years of age are usually injured at home.

(6) Comparisons by residence indicate that: (a) Rural-nonfarm persons have the highest rate of injury in moving vehicle accidents; (b) rural-farm residents have the highest rate of accidents in non-moving vehicles; (c) home accident rates are highest among the rural-nonfarm resident group.

(7) People who live on farms have the highest accident rates for five classes of accidents: (a) machinery in operation; (b) struck by an object; (c) caught by or crushed between two objects; (d) one-time lifting or exertion; (e) all other types of accidents. The nature of these accidental injuries suggests programs of safety can be designed for specific classes of accidents.

(8) The population of the United States annually experiences about 460 million restricted activity days due to injury, a rate of 261 days per 100 population. An annual average of 64 days per 100 population is spent in bed because of accidental injury and 126 days of work are lost annually per 100 persons 17 years of age and over.

(9) Rural-farm residents experience a considerably higher rate of restricted activity days, bed disability days, and work-loss days than do

urban and rural-nonfarm residents. These findings definitely establish the fact that accidental injuries while at work represent a higher per capita social and economic cost to farmers.

(10) Some 1,997 accidental deaths occurred in Louisiana in 1962. Of this number, 45 per cent occurred in places classified as rural. The data are not sufficiently detailed to determine what percentage of the injuries to rural residents occurred on farms.

(11) In Louisiana, major accidents apparently are more likely to occur on the larger farms. Education and safety consciousness are negatively correlated with major accidents.

(12) A majority of Louisiana farmers do not follow certain safety precautions such as prohibiting smoking in their barns, discussing a fire plan with family members, having on hand antidotes for toxic chemicals, and owning fire extinguishers.

(13) Farmers view accidents resignedly, attributing them to carelessness, illiterate and unskilled labor, and fate.

The above findings suggest that certain situational factors structure farming as an occupation in such a way as to encourage a high rate of accidents. These factors may be identified as: (1) social control factors, in the sense that farm social systems include relatively few social control mechanisms designed to enforce safety practices; (2) labor force factors related to the relatively high proportion of "substandard" or "marginal" labor employed on farms; (3) socio-psychological factors manifested in the attitude of farmers toward risk-taking.

In summary, the implication of the above analysis is that the high accident rate on farms can be largely accounted for in terms of the social and cultural environments within which farm work is done.

FARM ACCIDENTS

Number, Types, Social Costs and Causes

ALVIN L. BERTRAND
Professor, Departments of Sociology and Rural Sociology

Introduction

The accident problem has been subjected to increasing investigation the last 30 to 40 years. During this time, much has been learned about the nature and cause of accidents and some progress has been made in reducing both fatal and nonfatal accidents in the nation. However, despite the progress made, the social and economic costs of accidents remain at a high level, and constitute a social problem worthy of continued study and research.

One facet of the accident problem is of particular interest to persons in agriculture and related occupations. This is the fact that fatal and nonfatal accidents traditionally have been more frequent among persons living on farms than among persons engaged in most other occupations. Why residence has been so closely associated with accidents is not altogether clear, although some clues are available from past studies.[1] Nor is it known whether or not patterns of accidents are continuing today as they have in the past. These two important questions were the focus of the research undertaken and reported here.

The report which follows directs attention to: (1) the magnitude of the accident and injury problem and differences of this nature among the various residence groups, (2) the safety practices and other correlates of accidents for a sample of Louisiana farmers, and (3) the analysis of the findings in terms of a theoretical frame of reference.

Objectives

The first specific objective of the research undertaken was the determination of the magnitude of the accident rate and of differentials in the number and type of accidents in farm and nonfarm areas. In this regard, national data on nonfatal but disabling accidents have not been available until recently. The U. S. Department of Health, Education and Welfare inaugurated a National Health Survey in the latter 1950's. This survey has provided authentic information for the first time on nonfatal injuries and other disabilities of individuals living in urban, rural-nonfarm and rural-farm places. States and local reporting units do not generally report accident data in this manner, although special tabulations of this type are occasionally done.

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[1] Two comprehensive studies are: Prodipto Roy, "Selected Environmental and Human Factors Associated With the Incidence of Accidents to Farm People in Pennslyvania," unpublished Ph.D. dissertation, Department of Agricultural Economics and Rural Sociology, Pennsylvania State University, 1957; and Saad M. Gadalla, *Selected Environmental Factors Associated With Farm and Home Accidents in Missouri,* Columbia, Missouri, Agricultural Experiment Station Research Bulletin 790, 1962.

The second objective of the study was to compare rural and urban accident experiences in order to determine the nature of possible pattern differentials. It was hypothesized that both the causes and the nature of accidents would vary considerably from city to country, with rural people being more frequently involved in accidents related to mechanical contrivances and more frequently being seriously hurt.

The third objective and final one was to uncover, if possible, the factors contributing to the high level of farm accidents. Many factors need investigation in this regard. It is not clear from previous study whether or not technology is the most important variable in farm accidents. Innovations never stop and after each new purchase, the farmer has to learn new operational procedures, which in turn require some change in his behavior pattern. The extent to which the structure and functioning of farming systems tend to encourage accidents is also not clear. These and other factors served as the focus of investigation in connection with the above objectives.

Source of Data

Fortunately for the investigator, the statistics relating to accidents from the National Health Survey were published in late 1962 and early 1963. Thus, information on types of injuries, days lost from injuries, and other aspects of the accident picture were available for this report. The procedure was to assemble the data from the National Health Survey into tables appropriate to the objectives of this study. In addition, charts were prepared to highlight certain comparisons and patterns. Insofar as is known, this is the first attempt to systematically analyze these particular aspects of the Survey's findings.

For those persons who are not familiar with the National Health Survey, it may be noted that it is a continual operation. Each week a sample of the civilian, noninstitutional population throughout the United States is studied. The reports used in this analysis included 104 weeks of interviews extending over two years (July 1959 - June 1961). Interviews were conducted in approximately 76,000 households that included some 250,000 persons. The questionnaire used and the over-all design and plan of the study appear in the reports of the National Health Survey.[2]

The annual estimates that are included in the tables are estimates based on the number of persons injured or otherwise affected who were living in the household at the time of the interviews. In each instance, the sample population was expanded proportionately to the estimated total population. Since all the estimates are based on a family population rather than an entire population, they are subject to a sampling error. The sampling errors, for the most part, are of relatively low magnitude. Where the sampling errors are high, i.e., they do not fall in acceptable ranges, notation is made.

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[2] See: Health Statistics, U. S. National Health Survey, U. S. Department of Health, Education and Welfare, Series A (-4) and Series B (37-42), 1958-1963.

Louisiana data for this study were obtained from a field survey which was planned to obtain information relative to farmers' safety practices and other characteristics which might be associated with accidents. The survey was worked out in consultation with Agricultural Extension Service specialists, public health specialists, agricultural engineers, and others. A comprehensive questionnaire was developed and used in the interview of household heads in carefully selected sample areas. The sample areas were drawn to include the major socio-cultural areas of the state (French-Catholic South Louisiana and Anglo-Saxon Protestant North Louisiana) and three major type-farming areas (sugar cane, rice, and cotton). Specifically, Assumption Parish was selected to represent the sugar producing areas of the state, Acadia Parish was selected to represent the rice producing areas of the state, and parts of Madison and Richland parishes were selected to represent the cotton producing areas of the state. Each sample area was divided into sampling units and segments, and an area probability sampling technique was used to select the particular farms where the interviews were to be completed. Altogether, data were obtained from 297 farms.

Definition of Terms

Several terms from the National Health Survey are used throughout this report and need clarifying. *Residence* as used by the National Survey and in this study signifies the usual division of the population into three residence classes: urban, rural-nonfarm, and rural-farm. The definition of rural and urban residence is the same as that used in the 1950 Census, as follows:

(1) *Urban.*—The urban population includes all persons living in (a) places of 2,500 inhabitants or more which are incorporated as cities, burroughs, or villages; (b) incorporated towns of 2,500 inhabitants or more except in New England, New York, and Wisconsin, where "Towns" are simply minor civil divisions; (c) the densely settled urban fringe including both incorporated and unincorporated areas around cities of 50,000 or more inhabitants; and (d) unincorporated places of 2,500 inhabitants or more outside any urban fringe. The remaining population is classified as rural.

(2) *Rural-Farm.*—The rural-farm population includes all rural residents living on farms. For National Health Survey purposes, the statement of the household respondent to the effect that the members of the household lived on a farm or ranch was accepted with the following exception: (1) A house occupied by persons who pay cash rent for the house and yard only was not counted as a farm or ranch even if the surrounding area was farm land. This special case did not cover: (a)

the living quarters of a tenant farmer who rented farm land as well as a house and yard; (b) the quarters of a hired hand who received living quarters on the farm as part of his compensation; or (c) separate living quarters inside a structure which was classified as being on a farm. In all cases the living quarters were counted as being on a farm.

(3) *Rural-Nonfarm.*—Included all the remaining rural population.

In the text which follows, when a reference is made to *accidents on farms,* all accidents occurring in farm buildings or on cultivated land are included. Accidents occurring in the farm home or premises are shown as *Home Accidents.*

In each instance, where age groupings appear, *age at last birthday* was recorded by single years and combined into groups.

Other terms, when used in a specific rather than a general context, are defined as they appear in the text.

The Incidence and Pattern of Accidental Injuries[3]

Data from the National Health Survey, as indicated, portrays the national picture insofar as accidental injuries are concerned. Although the focus in this study is rural-urban comparisons, a review of the findings for the population as a whole serves as a point of departure. Data are presented according to age, sex, and residence characteristics.

The Number of Persons Injured Annually

The U. S. Picture. It can be seen from Table 1 that 255.2 persons are injured annually per 1,000 population in the United States.[4] At this rate it is estimated that an average of 45 million persons per year sustain injuries sufficient to require attention or to restrict their usual activities. The magnitude of this rate, more than one out of every four persons, is sufficient to attract national concern, especially in the light of the many programs relating to accident prevention.

The National Health Survey data indicates males are more susceptible to accidents than females. Among the former, the injury rate was 301 per 1,000 while among the latter it was only 212 per 1,000 persons. Interestingly, the injuries received by male school age children and young adults were chiefly responsible for this phenomenon. (See Figure 1.) Apparently, two factors account for this fact. First, this age group has not achieved the safety habits of older persons. Second, their behavior patterns place them in situations which make them more

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[3] An *injury,* as used here, includes a condition such as fractures, lacerations, convulsions, burns, etc. which are commonly thought of as injuries. In addition, effects of exposure, such as sunburn; adverse reactions to immunizations or other medical procedures, and poisonings are so defined. The conditions included appear in the International Classification of Diseases as injury code numbers N800-N999.

[4] Annual estimates of the number of persons injured are derived from the count of persons who reported an injury during the two-week period prior to the week of interview.

TABLE 1.—Number of Persons Injured per 1,000 Population per Year, by Residence and Age: United States, July 1959 - June 1961

Residence and Age	Number of Persons Injured per 1,000 Population per Year			
	All Classes	Urban	Rural-Nonfarm	Rural-Farm
All Areas				
All Ages	255.2	252.5	267.3	240.6
0- 5	293.7	307.9	294.1	221.6
6-16	314.9	328.7	332.6	224.7
17-24	277.9	278.3	284.3	262.5
25-44	227.8	216.7	233.8	275.9
45-64	218.3	213.1	220.3	241.4
65+	189.5	180.7	208.2	202.5

Source: *Health Statistics From the U. S. National Health Survey,* Series B, No. 37, Table 18, U. S. Department of Health, Education and Welfare, Washington 25, D. C., October 1962.

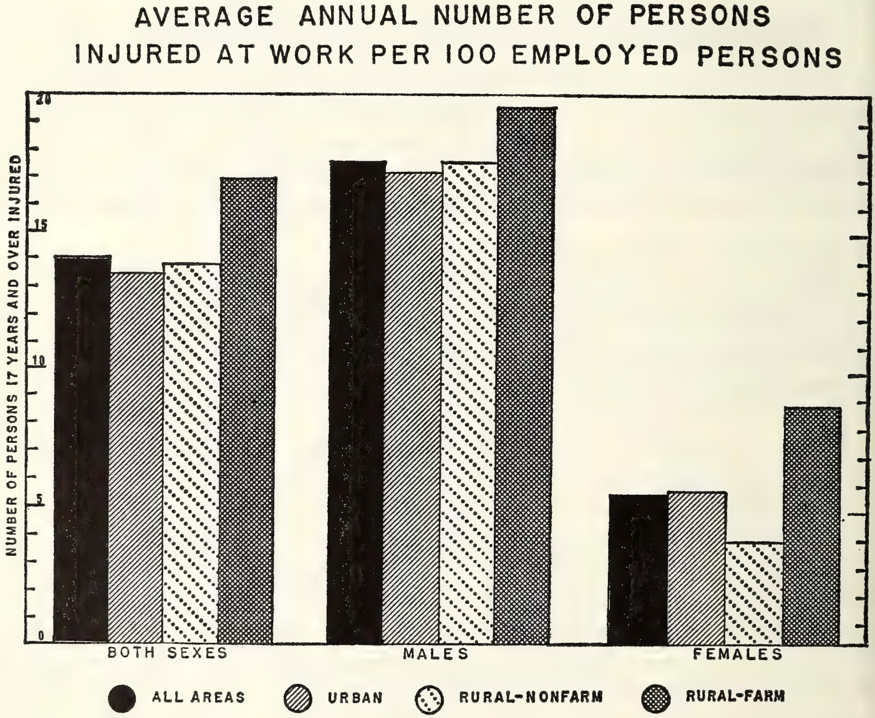

FIGURE I

susceptible to accidents. The fact that over four males out of ten in the ages 17-24 years are accidentally hurt each year is indeed a matter worthy of further investigation.

Residence Differences.—When *all* major injuries are considered among the three residence groups, rural-nonfarm residents have the highest annual accidental injury rate, 267.3 per 1,000 population (Table 1). *The lowest rate is found among persons who live on farms, 240.6 per 1,000 population.* This is a most important finding in terms of the purpose of the present study. Urban rates hold an intermediate position but are close to rural-nonfarm rates. Some 252.5 persons per 1,000 population living in cities are injured annually.

The higher rates of injury among rural-nonfarm and urban residents are principally due to the large number of injuries sustained by males in these areas. However, in all instances, accidental injuries increase to the early adult ages and then gradually decrease.

Why farm people as a whole should experience fewer injuries than non-farm people is difficult to explain. No doubt crowded conditions and other environmental factors are involved. There is need for more detailed study before a final conclusion can be reached. Previous reports have generally stressed that farm accident rates were unusually high, but usually failed to show that people living on farms sustain fewer injuries, relatively, than persons not living on farms.

The Number of Persons Injured Annually While At Work

The place where a person is injured is an important clue to accident cause and prevention. It is also an important commentary on the behavior pattern of occupational groups which represent distinct subcultures within the greater society.

The U. S. Picture.—The data collected in the 1961-62 National Health Survey indicate that an average of about 9 million persons sustained injuries annually while at work. The 9 million persons comprised about 20 per cent of the total number of persons injured annually in all accidents, that is, both work and non-work accidents. This is a significant figure in that it highlights the fact that eight out of ten injuries occur in non-work situations.

Age differentials again indicate that younger persons, in this instance, 17-24 years of age, have higher rates (number per 100) of accidents. In fact, for the U. S. as a whole, accident rates while at work decline steadily with advancing age of employees. (See Table 2 and Figure 2.) A comparison of accidents while at work shows men to have a much higher rate than women. However, contrary to male patterns, older females have a slightly higher accident rate than younger females.

Residence Differences.—Of the 9 million persons injured annually while at work during the year of the study, approximately 1,219,000 were farm residents, 2,441,000 lived in rural areas but were not occupied in agriculture, and the remaining 5,437,000 lived in urban places. In terms of the totals, it can be seen that the majority of all work accidents occur in urban places. However, when accident rates are computed, such as the number per 100 currently employed persons, a different picture arises. In both the urban and rural-nonfarm groups, about 13

TABLE 2.—Average Annual Number of Persons Injured[1] While at Work per 100 Currently Employed Persons per Year, by Residence, Sex, and Age: United States, July 1959 - June 1961

Sex and Age	Residence			
	All Areas	Urban	Rural-Nonfarm	Rural-Farm
Both Sexes				
All Ages—17+	13.3	12.8	13.2	16.7
17-24	15.6	14.0	19.1	17.8
25-44	13.5	12.6	13.7	18.8
45-64	12.7	13.2	9.8	15.4
65+	9.2	7.6	(*)	(*)
Male				
All Ages—17+	17.4	17.0	17.4	19.3
17-24	23.1	19.9	30.2	24.9
25-44	17.6	16.7	17.7	22.3
45-64	16.0	17.0	13.3	16.5
65+	10.3	11.8	(*)	(*)
Female				
All Ages—17+	5.3	5.5	3.7	8.5
17-24	4.9	6.5	(*)	(*)
25-44	4.5	4.5	(*)	(*)
45-64	6.2	6.8	(*)	(*)
65+	(*)	(*)	(*)	(*)

[1] Includes only currently employed persons with work injuries involving one or more days of restricted activity, or medical attention.

*Magnitude of sampling error precludes showing separate estimates.

Source: *Health Statistics From the U. S. National Health Survey,* Series B, No. 41, Table 4, February 1963.

persons per 100 are injured annually while on the job. Amongst rural-farm persons, this figure jumps to approximately 17. The same pattern persists for both males and females, although males usually have considerably more injuries.

The above finding that farm groups experience relatively more accidents while engaged in work is a key one. The reason for this pattern is undoubtedly to be found in the complex of the work situation. It suggests that accident prevention programs for farmers should concentrate on work situations and hazards. The latter point will be expanded in the last section of this report.

When an analysis of the data on injuries while at work is done according to age groups, an interesting discovery is made. A larger relative number of persons from 25 to 64 years of age are injured on farms, but relatively more persons 17 to 24 years of age are injured off the farm. Why this is true is not too clear. Possibly jobs which are available to younger persons are more likely to be hazardous, or to be done without benefit of an apprenticeship. It could also be that younger city persons work at jobs which are not so closely supervised and controlled.

The Cause and Circumstances of Accidents

It was hypothesized for purposes of this study that the cause and circumstances of accidents would differ significantly for farm and nonfarm places. Fortunately, data collected in the National Health Survey permitted testing this hypothesis in a general way. Tables 3 and 4 were

TABLE 3.—Number of Persons Injured[1] per 1,000 Population per Year, by Residence, Age, and Class of Accident: United States, July 1959 - June 1961

Residence and Age	Class of Accident				
	Moving Motor Vehicle	Non-Moving Motor Vehicle	While at Work	Home	Other and Unknown
All Areas					
All Ages	16.4	10.7	46.4	106.5	75.3
0- 5	(*)	8.9		209.5	71.6
6-16	14.8	11.6		128.6	159.8
17-24	32.5	13.8	79.9	57.0	94.8
25-44	17.2	11.8	81.1	73.7	44.0
45-64	18.8	7.3	77.8	78.0	36.3
65+	13.7	11.9	18.3	110.9	14.7
Urban					
All Ages	13.0	10.2	47.2	103.6	78.5
0- 5	(*)	9.3		218.1	76.7
6-16	10.8	10.9		138.0	169.1
17-24	13.8	12.4	74.7	62.2	113.2
25-44	16.4	10.0	76.6	66.9	46.8
45-64	14.4	7.5	82.7	72.2	36.2
65+	16.5	14.5	15.9	96.9	36.8
Rural-Nonfarm					
All Ages	26.2	9.6	40.4	119.1	72.0
0- 5	(*)	(*)		225.2	57.8
6-16	26.2	9.3		139.5	157.6
17-24	79.7	(*)	83.2	47.0	54.7
25-44	21.9	10.0	81.0	80.1	40.8
45-64	(*)	54.8	85.0	40.6	85.0
65+	(*)	(*)	(*)	137.5	31.7
Rural-Farm					
All Ages	10.7	15.4	55.6	91.4	67.4
0- 5	(*)	(*)		123.1	85.0
6-16	(*)	19.4		70.1	129.5
17-24	(*)	(*)	100.3	49.5	68.0
25-44	(*)	28.6	108.5	94.8	36.3
45-64	(*)	(*)	94.5	94.7	28.9
65+	(*)	(*)	(*)	137.3	(*)

[1] Includes only persons with injuries involving one or more days of restricted activity.

*Magnitude of sampling error precludes showing separate estimates.

Source: *Health Statistics From the U. S. National Health Survey*, Series B, No. 37, Table 3, U. S. Department of Health, Education and Welfare.

TABLE 4.—Number of Persons Injured[1] per 1,000 Population per Year, by Detailed Type of Accident and Residence: United States, July 1959 - June 1961

Detailed Type of Accident	Residence			
	All Areas	Urban	Rural-Nonfarm	Rural-Farm
Total persons injured	225.2	252.5	267.3	240.6
Moving motor vehicle	16.4	13.0	26.2	10.7
Uncontrolled fire, explosion, or discharge of a firearm	2.2	2.5	2.4	(*)
Nonmotor vehicle, in motion	5.0	4.6	7.2	(*)
Machinery, in operation	7.4	7.2	7.5	8.5
Cutting or piercing instrument	15.2	12.5	20.9	15.9
Foreign body in eye, windpipe, or other orifice	6.7	5.0	10.3	6.9
Injury caused by animal or insect	10.4	8.1	15.2	11.0
Falls, on stairs, steps, or from a height	24.4	26.3	21.8	21.0
All other falls	44.0	48.4	39.7	32.5
Bumped into object or person	19.8	22.7	17.6	10.1
Struck by moving object	23.3	24.1	17.6	32.5
Handled or stepped on rough object	14.3	12.4	19.3	12.2
Caught in, pinched, or crushed between two objects	10.7	9.0	11.9	16.4
Came in contact with hot object or open flame	7.5	8.4	6.6	5.2
One-time lifting or exertion	12.5	12.1	12.2	15.6
Twisted or stumbled	10.2	11.4	8.9	7.0
Therapeutic misadventure	7.8	7.6	8.8	6.2
All other types of accidents	17.4	17.3	13.4	27.4

[1] Includes only persons with injuries involving one or more days of restricted activity or medical attention.

*Magnitude of sampling error precludes showing separate estimates.

Source: *Health Statistics From the U. S. National Health Survey,* Series B, No. 37, Table 3, U. S. Department of Health, Education and Welfare, October 1962.

prepared to show certain details of accidents for the various residence groups. In keeping with previous discussions, the U. S. picture is described first and followed by residence comparisons.

The U. S. Picture.—On the basis of findings from the National Health Survey, it is estimated, as pointed out previously, that a total 255 persons are injured per 1,000 population annually. Of this number, some 27 persons are injured in motor vehicle accidents (moving and non-moving), 46 persons in accidents while at work, 107 persons in home accidents, and 75 persons in miscellaneous accidents. The latter consists mainly of accidents occurring in public places such as schools, stores, offices, and recreation places, plus injuries resulting from reactions to medical procedures or treatments of one type or another.

When motor vehicle accidents were considered separately, it was found that almost 5 million (4,771,000) persons sustained such accidents annually.[5] Of this number 2,890,000 suffered injury from accidents involving moving vehicles and 1,881,000 from accidents in non-moving vehicles. Of the latter, the data collected indicated over one-third (35.4 per cent) were injured in accidents classified as "caught in, pinched or crushed," while 15.3 per cent were injured in falls. Interestingly, over two-fifths (41.6) of the non-moving motor vehicle accidents occurred at home.[6] Only 27.5 per cent of the non-moving vehicle accidents occurred on a street or highway.

Table 4 was prepared to show the number of persons injured, by detailed type of accident. Among persons reported injured, the largest number, an estimated 12 million nationally (27 per cent), were involved in accidents described as falls. According to these estimates, some 68.4 persons per 1,000 population suffer injuries of this type annually. Other types of injury found to occur frequently included: (1) being struck by a moving object other than a moving vehicle, (2) bumping into an object or person (including striking or kicking), and (3) being injured by a cutting or piercing instrument.

When accidents are tabulated according to age, it can be seen that children, youths, and persons over 65 years of age are usually injured at home. Persons ranging in age from 17 to 44 years are injured in greater relative numbers while at work. Not unexpectedly, in light of differential automobile insurance rates, persons aged 17 to 24 years had by far the highest rate of moving motor vehicle accidents.

Residence Differences.—It has already been demonstrated that rural-farm persons have higher rates of work injuries than nonfarm persons. Thus, it can be expected that the cause and circumstances of farm located injuries would usually be something related to a work situation.

Study of the data obtained in the National Health Survey on general class of injury shows that the rate of injuries in moving vehicle accidents was approximately twice as high for rural-nonfarm residents as for urban and rural-farm residents. The high degree of mobility among the rural-nonfarm males accounts largely for this differential. One can surmise that this pattern is a function of commuting some distance to work, shopping, recreation, and other places.

When findings relative to non-moving motor vehicle accidents are scrutinized, a different pattern emerges. The highest rate (1.5 persons per 100) occurs among rural-farm residents. One may conjecture that this phenomenon results from the common practice among farmers of operating, repairing, and maintaining many varied pieces of machinery and equipment.

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[5] For purpose of the National Health Survey a "motor vehicle" was defined as "any mechanically or electrically powered device, not operated on rails, upon which or by which any person or property may be transported or drawn upon a local highway. Any object, such as a trailer, coaster, sled, or wagon, being towed by a motor vehicle is considered part of a motor vehicle. Devices used solely for moving persons or materials within the confines of a building and its premises are not counted as motor vehicles."

[6] Home was considered the place of accidents if the injury occurred outside the home but within the property boundaries of the home.

Home accident rates were determined to be higher among the rural-nonfarm residence groups, with persons dwelling on farms experiencing the lowest rate for such accidents. There is no great difference among the three residence groups in rates of accidents classed as "other or unknown," although slightly more accidents of these types appeared in an urban setting.

A study of detailed types of accidents brings out the fact that farm people had the highest rate of accidents for five classes of accidents: (1) machinery in operation, (2) struck by an object, (3) caught by or crushed between two objects, (4) one-time lifting or exertions, (5) all other types of accidents. Each of these five classes represents a type of accident which would ordinarily be associated with a common farm situation. By contrast, urban persons were involved more frequently than other residence groups in accidents relating to falls, accidents having to do with coming in contact with hot objects or open flames, twisting or stumbling accidents, and accidents due to uncontrolled fire, explosions, or discharge of a firearm. The rural-nonfarm population, as noted, led in accidents associated with motor vehicles in motion, and also led in injuries sustained from coming in contact with cutting or piercing instruments and from handling or stepping on rough objects.

The above findings indicate there are enough differences between residence groups in cause and circumstances of accidents to warrant special study. When these factors are isolated, the problem of safety and control can be lessened. Safety programs, for example, could be designed to apply to specific known situations, rather than spread thinly in an attempt to serve for a general class of accidents about which detailed information is lacking.

Selected Aspects of the Social Cost of Accidental Injuries

The costs of accidents may be measured in a number of ways. Probably the most common practice is to convert work days lost and health care expenditures into dollar costs. Such a procedure is subject to a strict economic interpretation and does not account for other types of social costs, such as human suffering and the disruption of normal activities. The latter are intangibles, of course, and not subject to quantitative expression. In the analysis which follows no attempt is made to convert the data into dollar cost figures, which would be arbitrary at best. The interested reader can do this quite simply by multiplying days lost by average wage rates, and he may multiply hospital and disability days by some standardized rate. Related social costs are matters of insight and imagination.

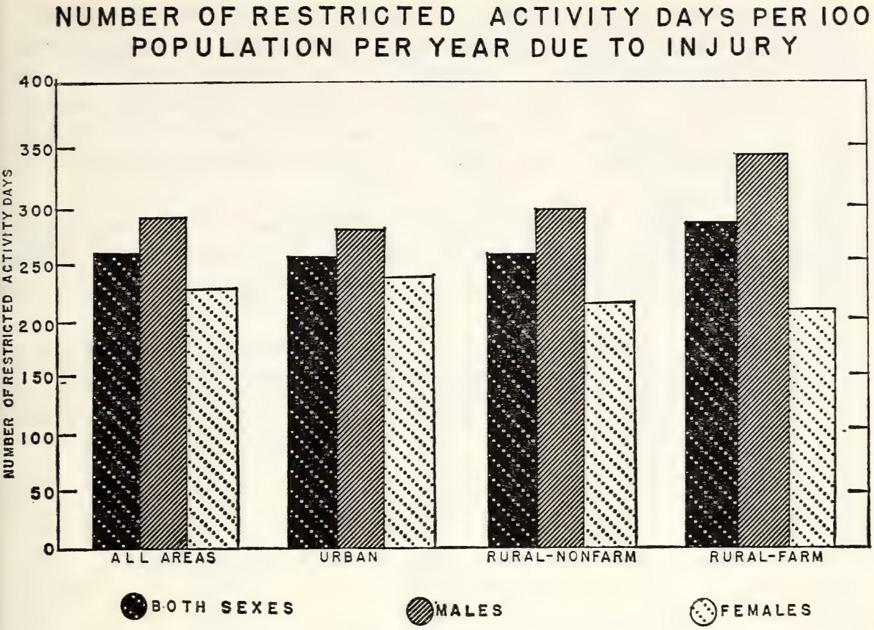

FIGURE 2

The U. S. Picture.—The specific social cost of accidents which were studied are: work-loss days, restricted activity days, and bed disability days.[7] Data for work-loss days are shown only for those ages which normally encompass the active work force. The restricted activity and disability days are shown for all ages.

The estimates derived from the data collected by the National Health Survey through household interviews indicate that the civilian non-institutional population of the United States annually experiences about 460 million restricted activity days due to injury. Some 113.5 million of these days are also bed disability days. Persons employed (17 years and over) had an estimated 8.3 million work-loss days, and children (6 to 16 years) lost 11.9 million school days. Almost one-fourth (23 per cent) of the 45 million persons estimated to be injured annually were determined to have one or more days of bed disability associated with their injury. Some 83.7 per cent of the injured received medical attention.

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[7] The following definitions were used in the National Health Survey: *Work-Loss Day*—a day a person normally would have gone to work but could not because of illness or injury. Regular work days less than a whole day were counted as whole days. *Disability Day*—the following terms were used in determining a disability day: hospital days, restricted activity days, bed disability days, and days lost from work. *Restricted Activity Days* are those in which a person reduces substantially his normal amount of activity because of a specific injury or illness.

The number of restricted activity days per 100 population is shown by residence, sex, and age groups in Table 5. As may be seen, activity-restricting injuries are extremely low among the younger age groups, i.e., from 0 to 5 years of age. Such injuries gradually increase with age, reaching a peak of 608.1 days per 100 persons in the 65-and-over age group. Males have higher rates of restricted activity than females at all ages.

It is revealing to learn that for each 100 persons in the nation, an average of 64 days a year is spent in bed because of injuries. (See Table 6.) Survey data indicate males spend somewhat more time (69 days per

TABLE 5.—Number of Restricted Activity Days per 100 Population per Year Due to Injury, by Residence, Age, and Sex: United States, July 1959 - June 1961

Residence and Age	Both Sexes	Male	Female
All Areas			
All Ages	260.9	291.3	232.1
0- 5	61.4	63.3	59.4
6-16	135.3	169.2	100.0
17-24	193.7	273.0	124.7
25-44	270.2	339.3	206.7
45-64	399.7	410.5	389.7
65+	608.1	608.3	608.0
Urban			
All Ages	257.9	277.7	239.8
0- 5	71.7	75.1	68.2
6-16	141.0	182.7	98.4
17-24	174.1	245.2	114.0
25-44	275.3	341.7	215.1
45-64	375.9	359.0	390.7
65+	523.4	476.4	558.5
Rural-Nonfarm			
All Ages	257.7	295.4	220.9
0- 5	50.5	43.5	57.6
6-16	133.8	161.7	104.1
17-24	232.9	358.9	129.6
25-44	258.9	329.1	193.7
45-64	401.2	420.6	381.4
65+	834.2	876.6	796.7
Rural-Farm			
All Ages	283.3	344.5	218.0
0- 5	40.8	60.0	(*)
6-16	116.8	135.4	96.9
17-24	217.7	251.6	179.3
25-44	273.2	355.8	193.9
45-64	519.0	626.9	399.7
65+	650.6	744.2	543.6

*Magnitude of sampling error precludes showing separate estimates.

Source: *Health Statistics From the U. S. National Health Survey,* Series B, No. 40, Table 1, February 1963.

TABLE 6.—Number of Bed Disability Days per 100 Population per Year Due to Injury, by Residence, Age, and Sex: United States, July 1959 - June 1961

Residence and Age	Both Sexes	Male	Female
All Areas			
All Ages	64.4	68.6	60.4
0- 5	27.2	25.9	25.5
6-16	31.1	36.1	25.8
17-24	34.2	45.1	24.6
25-44	68.4	84.7	53.4
45-64	98.9	101.4	96.5
65+	147.1	130.0	161.1
Urban			
All Ages	62.8	68.8	58.3
0- 5	29.1	29.7	28.5
6-16	31.9	40.0	23.6
17-24	31.7	44.9	20.5
25-44	71.5	88.2	56.3
45-64	93.2	97.6	89.3
65+	113.5	88.0	132.5
Rural-Nonfarm			
All Ages	66.7	65.7	67.7
0- 5	30.0	22.2	38.0
6-16	28.8	29.7	27.9
17-24	40.4	45.4	36.3
25-44	62.4	72.4	53.1
45-64	109.7	113.8	105.6
65+	227.0	179.5	269.0
Rural-Farm			
All Ages	66.8	78.6	54.2
0- 5	(*)	(*)	(*)
6-16	32.9	35.7	30.0
17-24	34.5	45.5	(*)
25-44	68.1	100.8	36.7
45-64	108.3	96.6	121.2
65+	181.7	230.7	125.6

*Magnitude of sampling error precludes showing separate estimates.

Source: *Health Statistics From the U. S. National Health Survey,* Series B, No. 40, Table 2, February 1963.

100 persons) in bed because of injuries than females (60 days per 100 population). The number of bed disability days due to injury increases as age increases, reaching 147 days per 100 persons in the 65-years-and-over age class. However, older women (65 years and over) are bedridden because of injury more than men in this age group.

Work-loss days because of injury represent a more readily calculable economic cost to the nation. According to the data collected, among every 100 persons 17 years of age and over currently employed, 126 days of work are lost annually because of injury. Males lose an average of 145 work days due to injury per 100 employed, while females lose 87

NUMBER OF BED DISABILITY DAYS PER 100 POPULATION PER YEAR DUE TO INJURY

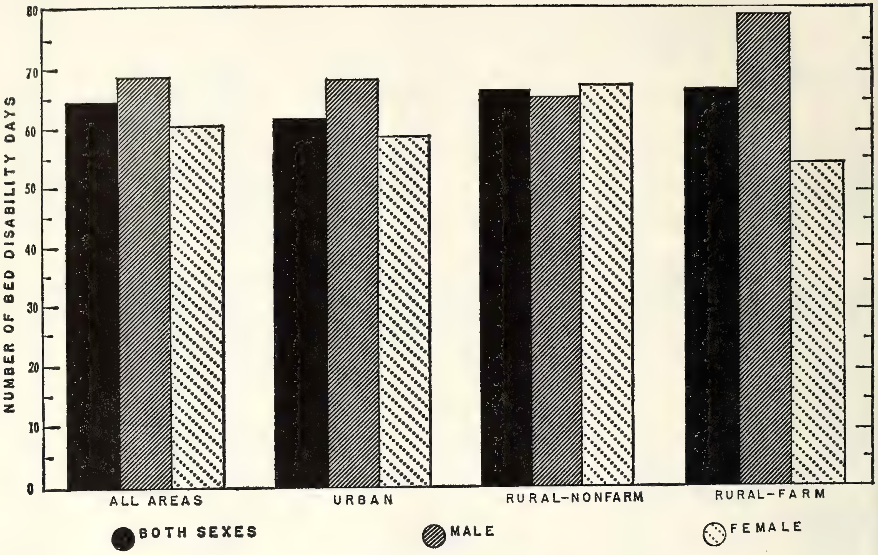

FIGURE 3

NUMBER OF WORK DAYS LOST PER YEAR PER 100 EMPLOYED MALES BY AGE GROUP

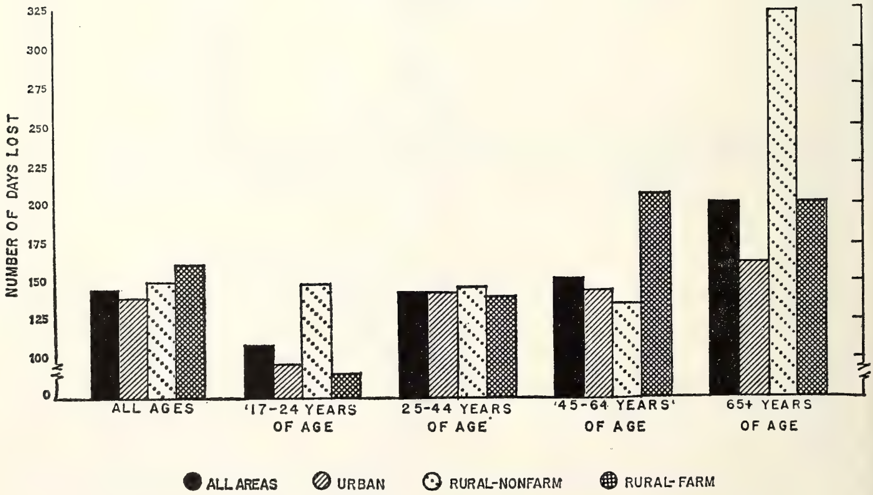

FIGURE 4

days per 100 employed. The older women (65 year and over), in contrast to women in all younger age groups, lose more days due to injury than men in their corresponding age bracket.

Residence Differences.—The rural-farm population experienced a considerably higher rate of restricted activity days than the urban or rural-nonfarm population. As shown in Table 5, persons living on farms annually experience 283 days of disability for every 100 population, while city dwellers and rural-nonfarm residents of all ages have 258 days of disability annually per 100 persons. Interestingly, study of age distribution indicates that urban persons under 16 years of age have a higher rate of activity-restricting days than both rural-farm and rural-nonfarm persons in these ages. The pattern reverses amongst older age groups, with rural-nonfarm persons 65 years and over having

TABLE 7.—Average Annual Number of Work-Loss Days and Number of Work-Loss Days per 100 Currently Employed Persons per Year Due to Injury, by Residence, Age, and Sex: United States, July 1959 - June 1961

Residence and Age	Average Number of Work-Loss Days in Thousands			Number of Work-Loss Days per 100 Currently Employed Persons per Year		
	Both Sexes	Male	Female	Both Sexes	Male	Female
All Areas						
All Ages	83,773	64,112	19,661	125.5	144.8	87.4
17-24	7,084	6,277	807	72.1	108.8	19.9
25-44	36,239	29,603	6,636	120.9	143.7	70.8
45-64	33,500	23,744	9,756	141.0	151.5	120.7
65+	6,950	4,487	2,463	215.9	201.1	249.3
Urban						
All Ages	52,525	37,480	15,045	123.6	139.2	96.6
17-24	4,135	3,501	634	64.7	98.3	22.4
45-64	21,865	14,335	7,529	140.0	146.2	129.5
65+	4,412	2,205	2,207	208.6	162.6	290.8
Rural-Nonfarm						
All Ages	20,944	17,676	3,268	123.3	150.1	62.7
17-24	2,148	2,014	(*)	95.3	147.8	(*)
25-44	10,888	9,188	1,700	123.9	146.4	67.8
45-64	6,264	5,086	1,178	116.9	137.0	71.6
65+	1,644	1,388	(*)	277.7	324.3	(*)
Rural-Farm						
All Ages	10,304	8,956	1,348	141.6	161.0	78.6
17-24	801	762	(*)	67.7	90.1	(*)
25-44	3,238	2,977	(*)	115.2	140.6	(*)
45-64	5,371	4,322	1,048	193.6	299.7	168.5
65+	895	895	(*)	175.1	199.8	(*)

*Magnitude of sampling error precludes showing separate estimates.

Source: *Health Statistics From the U. S. National Health Survey,* Series B, No. 40, Table 3, February 1963.

the highest rate of restricted activity days of the three residence groups.

One interesting observation can be made from the data relating to bed disability days. That is, the number of disability days per 100 males shows an inverse correlation to population density insofar as the latter is expressed in residence terms. In other words, the highest rate of bed disability is in rural-farm areas. This pattern is not so clear-cut for the farm population as a whole because females on farms have fewer days of bed disability per 100 population than females in rural-nonfarm areas or in cities.

Employed farm persons 17 years of age and over lose more work days each year per 100 persons than do employed urban or rural-nonfarm persons of this age. However, this is true only because of the high number of work days per male employed on farms. Females employed on farms lose fewer days than employed urban females, relatively speaking. However, employed rural-nonfarm females have the lowest work-loss rate of all. (See Table 7.)

The above findings are of importance to persons interested in improving the efficiency of agriculture. *They definitely establish the fact that accidental injuries while at work represent a higher cost to farmers than to urban or rural-nonfarm workers.*

Accidental Deaths in Louisiana—1962

It has already been pointed out that statistics on nonfatal accidents are not collected at the state level in Louisiana. However, fatal accidents are officially recorded, and these data provide some indication of the importance of accidents in the state. Through the cooperation of the Louisiana State Department of Health, it was possible to include the latest available data on accidental deaths in the state in this report. The writer wishes to acknowledge, in addition, special tabulations made by State Department of Health personnel which show accidental deaths according to residence.

Altogether, 1,997 accidental deaths occurred in Louisiana during 1962. Only 12 of the individuals who died accidentally in the state maintained a permanent residence outside of the state. Table 8 has been prepared to show the accidental deaths in the state by parish, by race, and by residence. It will be noted that some 892 deaths occurred to people in places classified as rural. This is 44.7 per cent of the total number of accidental deaths.

No attempt is made here to analyze accidental deaths according to geographic distribution. It can readily be seen, however, that south Louisiana parishes have more accidental deaths classified as rural than do north Louisiana parishes. A special study is needed to determine whether this is a function of population density or of other factors. The writer is of the opinion that type-farming and other cultural differences help account for this differential.

TABLE 8.—1962 Accidental Deaths in Louisiana, by Parish, Residence, and Race

Parish	Total	Residence		Race	
		Urban	Rural	White	Nonwhite
Acadia	27	13	14	22	5
Allen	14	7	7	10	4
Ascension	16	4	12	9	7
Assumption	10	—	10	4	6
Avoyelles	32	7	25	18	14
Beauregard	8	4	4	7	1
Bienville	10	1	9	7	3
Bossier	21	6	15	11	10
Caddo	106	85	21	66	40
Calcasieu	58	39	19	51	7
Caldwell	5	—	5	3	2
Cameron	4	—	4	2	2
Catahoula	6	—	6	5	1
Claiborne	8	4	4	3	5
Concordia	7	4	3	1	6
DeSoto	19	4	15	5	14
E. Baton Rouge	93	62	31	66	27
E. Carroll	13	4	9	4	9
E. Feliciana	9	—	9	6	3
Evangeline	25	6	19	15	10
Franklin	18	3	15	11	7
Grant	6	—	6	5	1
Iberia	33	17	16	24	9
Iberville	15	3	12	7	8
Jackson	8	4	4	5	3
Jefferson	106	35	71	84	22
Jefferson Davis	14	8	6	10	4
Lafayette	49	35	14	39	10
Lafourche	39	11	28	32	7
LaSalle	4	—	4	3	1
Lincoln	9	4	5	5	4
Livingston	22	6	16	18	4
Madison	16	7	9	7	9
Morehouse	23	6	17	5	18
Natchitoches	21	5	16	8	13
Orleans	335	335	—	213	122
Ouachita	50	34	16	36	14
Plaquemines	21	—	21	13	8
Pointe Coupee	10	2	8	3	7
Rapides	60	31	29	37	23
Red River	9	—	9	5	4
Richland	15	4	11	8	7
Sabine	16	3	13	11	5
St. Bernard	26	—	26	21	5
St. Charles	18	—	18	9	9
St. Helena	11	—	11	4	7
St. James	5	—	5	1	4
St. John	9	—	9	4	5
St. Landry	55	19	36	26	29
St. Martin	13	4	9	11	2
St. Mary	27	13	14	19	8

(Continued)

TABLE 8 (Continued)

Parish	Total	Residence		Race	
		Urban	Rural	White	Nonwhite
St. Tammany	22	9	13	17	5
Tangipahoa	56	20	36	33	23
Tensas	11	—	11	—	11
Terrebonne	42	16	26	32	10
Union	16	5	11	9	7
Vermilion	10	5	5	10	—
Vernon	15	3	12	13	2
Washington	29	16	13	16	13
Webster	18	7	11	13	5
W. Baton Rouge	17	3	14	7	10
W. Carroll	11	—	11	6	5
W. Feliciana	5	—	5	2	3
Winn	9	—	9	8	1
Out of State	182	182	—	147	35
Totals	1,997	1,105	892	1,312	685

The Farm Accident Complex

The foregoing data from the National Health Survey made it clear that high rates of accidents are associated with agriculture as an occupation and not as a place of residence. In this regard, a clear distinction should be maintained between accidents occurring in rural-farm areas and those occurring as a result of farm work. Farms, when viewed as a place of residence, have relatively low accident rates. *However, farm work is more closely associated with accidents than nonfarm work,* and this is the concern of the remainder of the present report.

Since the National Health Survey was not designed to show the relationship of accidents to a complex of socio-economic factors, a survey of this nature was planned, as brought out previously, for a sample population in the state. The field study planned in Louisiana was designed to shed light on farming practices and attitudes of farmers which might account for their accident proneness. This approach was in keeping with the hypothesis that farming as an occupation is more conducive to accidents because of certain socio-cultural factors. The safety precautions taken on farms were considered especially pertinent to accidents.

Factors Related to Farm Accidents in Louisiana

At this point, the reader may be reminded that the data presented are for the sample areas described in the introduction to this report. It was determined that some 32 major accidents (including 8 deaths) occurred on the 297 sample farms during the year preceding the study and some 23 minor accidents occurred on these farms in the month previous to the study.[8] Major accidents were defined as *those which required professional medical attention or caused a restriction of normal activities for at least a day or caused a loss of 25 dollars or more in property damage.* Minor accidents were defined as *those serious enough to require some kind of attention before carrying on normal activities but not serious enough to restrict activity for a day.*

Accidents on farms were related to several independent variables. (See Table 9.) Percentage distributions were not calculated because the numbers were too small. For this reason, the data must be interpreted with caution and considered as case studies. Nevertheless, the patterns emerging are consistent and provide a basis for further study.[9]

The largest number of major accidents occurred on the largest farms. This is what would be expected, of course, in terms of the time, machinery, etc. involved. However, minor accidents were reported more often on the smaller farms. This appears as an inconsistency, and may be due to the difficulty of one respondent knowing about all minor accidents on a large farm. The same pattern of accidents occurs when total man-days worked are used as the independent variable. Farms with a thousand or more man-days worked annually, had by far the highest number of major accidents, while the farms with the lowest number of man-days worked had the highest number of minor injuries. The larger farms, in terms of value of farm machinery, had the higher rates of major accidents, but the smaller farms had the higher rates of minor accidents. This finding parallels the findings relating to size of operation. The pattern emerging from the study was for the farms with the highest levels of living to have the highest number of major accidents.

When education of the operator is related to accidents, it is clear that the better educated farmers had the least number of both major and minor accidents. Although this finding needs further testing, it provides insight as to the reasons for accidents.

The data indicate that middle-aged farmers are the ones who have the largest number of accidents, both major and minor. This is probably true because of their larger numbers. The data did not lend themselves to a rate study by age.

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[8] The findings paralleled those of similar studies in other states with few exceptions. See: *Selected Environmental Factors Associated With Farm and Farm Home Accidents in Missouri, op. cit.,* and "Selected Environmental and Human Factors Associated with The Incidence of Accidents of Farm People in Pennsylvania," *op. cit.*

[9] It is interesting to expand the findings of the study to include all farms in the state. Despite the obvious *roughness* of these data, it can be estimated that from 300 to 400 persons die in Louisiana each year as a result of farm accidents, that around 6,000 major farm acidents occur annually, and that 5,000 minor farm accidents occur each month. It should be noted that the estimates of deaths here are considerably larger than the records of the state Health Department show, but the writer feels reporting problems plus lower accident rates on non-commercial farms (residential and subsistence farms) account for this discrepancy.

TABLE 9.—Selected Socio-Economic Factors Related to Major and Minor Accidents Occurring on Farms in Sample Populations

Socio-Cultural Factors	Number of Major Accidents in Past Year	Number of Minor Accidents in Past Year
Total Farm Acreage per Farm		
1-249 Acres	10	14
250-449 Acres	4	3
450 and Over	18	6
Total Man-Days Worked per Farm		
0-499	4	11
500-999	8	8
1000 and Over	20	4
Levels of Living		
Low	1	0
Middle	11	16
High	20	7
Education of Operator		
1- 8 Years	21	16
9-12 Years	4	3
13 Years and Over	7	4
Age of Operator		
Under 39 Years	6	5
40 to 49 Years	16	10
50 Years and Over	10	8
Ownership Class		
Owner	20	13
Renter	12	10
Value of Farm Machinery per Farm		
Under $10,000	7	12
$10,000 and Over	25	11
Number of People Working per Farm		
Under 10	8	15
10-20	8	4
21 and Over	16	4
Operator's or Spouse's Attendance at Safety Meetings		
Yes	9	3
No	23	20

Owners were found to be more accident prone than renters for both major and minor accidents. This pattern can be explained, perhaps, in terms of their involvement in more risk situations in keeping with their ownership responsibilities.

Finally, it is interesting to note that those operators who attended safety meetings had the lowest accident rates in both the major and minor categories. Whether or not these meetings helped create a greater sense of safety is subject to conjecture. Neverthless, one is safe in hypothesizing that persons who attend safety meetings are more safety conscious.

Safety Precautions Normally Taken by Farmers

A list of safety precautions, including most safety measures which normally would be taken in connection with farming operations, was included in the questionnaire. The tabulated responses of interviewees are shown in Table 10. A study of the pattern of responses indicates safety practices can be grouped into three classes, including: Class I, those practices and precautions followed by at least 90 per cent of the farmers; Class II, those practices normally followed by at least half but not over 90 per cent of the interviewees; and Class III, those practices observed as a matter of course by less than half of the interviewees. The latter are of greatest significance to this study.

Class III safety precautions, those followed least often, included prohibiting smoking in barn, discussing fire plans with family members, having on hand antidotes for toxic chemicals, and ownership and accessibility of fire extinguishers. Admittedly, these are the types of precautions which are not usually followed in a family situation. Nevertheless, they oftentimes mean the difference between a serious accident and one not so serious. A quote from the written report of a field interviewer who questioned approximately half of the farmers is appropos here:

TABLE 10.—Safety Precautions Taken by Interviewees and Their Families

Safety Precautions	Percentage of Farms on Which	
	Precaution Normally Taken	Precaution Not Normally Taken
Prohibiting smoking in barn	34.0	66.0
Fire extinguishers	26.0	74.0
Approved electric wiring	90.0	10.0
Gasoline safely stored	95.0	5.0
Fire plan discussed	6.0	94.0
Printed instructions studied	96.0	4.0
Experienced machine operators	77.0	23.0
Safety guards installed	81.0	20.0
Instructions given on new machinery	98.0	2.0
Dangerous animals kept enclosed	97.0	3.0
Children warned of danger	100.0	0
Recommendations of manufacturers followed	97.0	3.0
Workers required to observe safety precautions	66.0	34.0
Antidotes for toxic chemicals on hand	17.0	84.0
Chemicals stored safely	96.0	4.0
Home checked periodically for fire hazards	96.0	4.0
Family members aware of safety precautions	95.0	5.0
Family sanitation conscious	96.0	4.0
First aid kit readily available	91.0	9.0

> Most respondents who reported that they allowed smoking in the barn claimed either that they had to because they could not keep their labor from smoking there or that there was no hay or anything in the barn to burn. Also, many of those who reported not allowing smoking in the barn were one-man farms where the farmer just did not happen to be a smoker. Others claimed that they did not allow smoking in the barn, but they knew that their hired help did smoke there, nevertheless.[10]

None of the respondents had fire extinguishers in their homes. Most of the farms that had fire extinguishers were the very large farms. They usually had them in the barn, shed, or shop. Very few had fire extinguishers on their equipment.

Safety precautions which were followed by over half but less than 90 per cent of the farmers interviewed (Class II) included: the use of experienced operators on farm machines, the installation of safety guards on equipment, and the requiring of workers to observe safety precautions.

Respondents' Opinions As to Why Farmers Have High Accident Rates

Each farmer interviewed was asked for his opinion as to why farmers had high rates of accidents. The majority of respondents, 56.5 per cent, said that carelessness was the most important factor in accidents. (See Table 11.) Approximately 12 per cent of the respondents said that "poor labor" was the main cause of accidents. Probing techniques determined that this expression carried the implication that illiterate, unskilled laborers tended to be ignorant of safety precautions. This finding suggests that some farmers do not set high qualification levels for their employees. Nearly one in eight interviewees said that machine complexity was the important reason for higher accident rates on farms, and one-seventh attributed accidents to *fate* or a miscellaneous variety of allied reasons. The implication in each instance was that such things were in the hands of other than mortal beings.

TABLE 11.—Respondents' Opinions as to the Reasons Farmers Have a High Accident Rate

Reason	Number	Per Cent
Carelessness	166	56.4
Job and machine complexity	37	12.6
Hurrying	14	4.8
"Poor labor"	35	11.9
"Fate and other"	42	14.3
Total	294	100.0

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[10] Written report prepared by John Drysdale, Graduate Assistant, Department of Rural Sociology.

Analysis of Findings

The Accident Syndrome

The many studies made of accidents suggest that a given accident is the culmination of an inevitable combination of factors found in the cultural background of the particular individual or group involved. In other words, while accidents may be capricious in and of themselves, the circumstances within which they occur are structured to a large extent. The combination of factors which together determine or influence accidents has been termed the *accident syndrome*.[11]

It has been determined that three sets of factors underlie most accidents: (1) environmental hazards; (2) temporary or prolonged personal impairment or maladjustment, and (3) faulty behavior under stress. The first set of factors is of primary importance to the sociologists, while the latter two sets are more the concern of psychologists. Assuming that personal impairment or maladjustment and faulty behavior under stress are personality variables not necessarily related to residence or occupation, then occupational differences in accident rates become a function of environment or "situation." This is the theoretical approach taken in the analysis of the findings presented in the preceding discussions.

Situational Factors in Farm Accidents

The significant findings with regards to the objectives of the present study of farm accidents may be summarized as follows: (1) Accident rates are higher for persons employed on farm jobs, when non-farm jobs are taken as a whole for comparison purposes. (2) The social cost of accidents measured in terms of days lost and disability days bears disproportionately on those persons engaged in agriculture as an occupation. (3) Certain precautions are not followed consistently by farmers. (4) Farmers view accidents resignedly, attributing their cause to carelessness, illiterate and unskilled labor, and fate.

The above findings point clearly to situational factors which structure farming as an occupation in such a way as to encourage accidents. Analysis of these findings suggests that three sets of situational (or environmental) factors are involved as follows: (1) social control factors; (2) labor factors; (3) socio-psychological factors. Each of these is closely related, of course. They may be elaborated as follows.

Social Control Factors.—The fact that more accidents occur on farms suggests differentials relating to procedure and practices. One of the first observations which can be made is that, compared with most industrial occupations, farm social systems do not have as many formal control mechanisms to make persons and groups systematically abide by safety precautions. This pattern of behavior can be validated by comparisons with non-farm industrial operations at almost any level. The latter, for the most part, have readily detectable mechanisms for controlling safety which have been imposed by insurance companies, by labor unions, and by management itself for economic as well as safety reasons. Periodic inspections and rigid supervision are provided as a matter of course, sometimes with the additional sanction of state, local, or federal government statutes. Not only are these mechanisms generally absent on farms, but national value orientations related to farming which favor individualism, free enterprise, and the like, provide strong negative sanction in this respect. According to the National Health Survey, more rural-farm persons, relatively speaking, are injured through being struck by a moving object, or caught in, pinched, or crushed between two objects, than are urban and rural-nonfarm persons. Injuries of these types are due to work hazards and could be prevented, ostensibly, with proper safety precautions. There is simply no mechanism built into farm social systems which assures that even minimum safety practices will be followed. Safety is more a matter of the individual operation than anything else.

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[11] Morris S. Schulzinger, "The Accident Syndrome," unpublished paper.

Labor Force Factors.—The second class of situational factors stems from the fact that farming tends to attract and tolerate what might be termed "substandard" or "marginal" labor to a disproportionate extent. Here the evidence is inductive and somewhat subjective in nature. The present study provided a clue in terms of farmers' verbalized reasons for accidents, and a review of prevailing work rates by occupation and industry substantiated that farm workers are paid less on the average.[12] The phenomenon of "poor" labor is not unrelated to the fact that there are fewer formal social control mechanisms in farming, but occurs at a different level of control than that of safety practices *per se*. That is, farm workers are not screened as carefully for mental, educational, and physical deficiencies as are industrial workers. One interviewer reports:

> Many of the respondents complained about the lack of availability of good labor. Many of the medium and large scale farm operators reported that even though their labor force (mostly Negroes) was experienced, they were not very competent. That is, most of these Negroes were born and raised on farms and usually had early experience with farm equipment, but their "attitude" was what the operators criticized, for the most part. Their attitude was generally described as one of carelessness, shiftlessness, irresponsibility, etc.
>
> On the small, one or two man farms, the answer was almost without exception that only experienced and competent men were allowed to operate the farm machinery. And I believe that this was true. A small farm operator usually cannot afford to risk his tractor operation to a hired hand (considering the type of labor available to him) even if he could afford to pay it.
>
> My impression was that worker instruction was minimal and restricted to bare essentials of operation. Many, however, did instruct their workers on care of machinery also. Some farmers had a somewhat fatalistic attitude about this—

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[12] For data on wages earned by farm workers, see: *Advance Report on the Hired Farm Working Force of 1962,* Farm Population Branch, E. R. S., U. S. D. A., October 1963. Rates in the South are especially low.

> "What good does it do me to preach to them about taking care of the equipment? They don't listen."[13]

One can hypothesize that comparative wage rates are such as not to attract the higher skilled, better educated worker, but this does not explain why farm wage rates are low. The important "situational" facts for this study are: (1) Substandard laborers lack the capacity to detect potentially hazardous situations and thus are more likely to become injured. (2) Farming as an occupation is more hazardous because of the necessity to deal with machinery, etc. under less "controlled" conditions. (3) Farmers employ "substandard" labor to a disproportionate extent. A fourth factor might be added to the effect that "substandard" labor does not insist upon safety devices and often misuses those devices provided.

Socio-Psychological Factors.—The third class of situational factors is quite different from the first two. It is manifest in the attitude of farmers toward risk-taking. The interviews conducted indicated that farmers as a group looked upon risk as a part of farm life and that it was a "poor" farmer who took the time to fully practice safety. Beyond this, there was a definite impression given that when risks, even dangerous ones, were taken in the interest of expediting work, the act was both "honorable" and status oriented. To be hurt or injured in such an undertaking provided one with an image of the "go-getter," the "doer," and other favorable stereotypes rather than of the careless and thoughtless person. In this regard, a clear distinction is made between accidents traceable to acts of bravado and those which emanated from ignorance or stupidity. In the former instance, the act was deliberate and done in full knowledge of possible consequences. The account of one of the interviewers is cogent:

> The third type of fatal tractor accident is mostly due to what could best be called "foolishness" or "madness" rather than just carelessness. Many farmers have tractors with hand clutches. These farmers (some of them) persistently misuse their tractors. Accidents typically happen in this manner — the driver backs up his tractor to a disc, puts it into neutral, and climbs down to hook on the disc. If he finds that he needs to pull up a couple of inches, he tries to operate the tractor while standing on the ground. He hand clutches the tractor with one hand and reaches down with the other hand to hook the disc to the drawbar. Because of the long reach his hand slips off the clutch and the tractor lunges forward in low gear. All the time he was working on the hooking up, his feet were no more than six or eight inches from the disc. Now the sudden forward motion of the tractor surprises him and it is almost impossible for him to get out of the way in that split second. And once his foot gets caught — well, he's bound to be run over completely by the disc. Now this sounds practically unbelievable, but a significant percentage of the deaths have happened in just this manner. And of those who have tractors with hand clutches, the practice of "hooking up" just described is unbelievably common.[14]

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[13] Written report by John Drysdale, Graduate Assistant, Department of Rural Sociology.

[14] *Ibid.*

Similar patterns of behavior have been observed in other occupational situations and accounted for in terms of compulsive drives, triggered by subconscious desires to show one's virility, etc. However, for attitudes and practices which become widespread in one occupational group, there must be a cultural sanction. Simply put, this means that farmers internalize such behavior patterns because they are promoted overtly or covertly in the subculture within which they participate.

Implications

The major implication of the above analysis is that the high accident rate on farms can be accounted for in terms of the social and cultural environment within which farm work is done. The environment is such as to: (1) discourage formal mechanisms for enforcing precautions; (2) encourage the employment of persons who are not capable of assessing the potential danger of given work situations; and (3) encourage the individual farmer to take foolish risks. These factors appear to have become so much a part of the agricultural subculture of the nation that it will require an intensive educational effort over a period of time to change this situation.

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Economic Status of
STATE-OWNED RURAL PROPERTIES
Acquired Through Tax Delinquency in Louisiana

Floyd L. Corty
Wayne D. Taylor

DEPARTMENT OF AGRICULTURAL ECONOMICS
AND AGRIBUSINESS
Louisiana State University and
Agricultural and Mechanical College
Agricultural Experiment Station
Charles W. Upp, Director

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Foreword

During the depression of the 1930's the problem of tax delinquency and adjudication of farm properties attracted considerable attention. A published report at that time indicated that between 1880 and 1937 a total of 24,655 tracts, or more than 2 million acres, were adjudicated to the state and remained unredeemed. Total assessed value of adjudicated land at that time amounted to nearly $15 million. Tax revenues lost because of adjudications were estimated to be $600,000 annually.

Since 1937, however, tax delinquency and adjudications have dwindled appreciably and as a consequence have attracted very little attention. This report updates to 1960 the data on rural tax delinquency and adjudications in Louisiana and at the same time explains the status of rural properties acquired by the state through tax delinquency.

Acknowledgments

Appreciation is expressed to Ellen Bryan Moore, Register of the State Land Office, Mr. Ory G. Poret, Executive Assistant, and other State Land Office personnel for their complete cooperation and assistance.

Recognition is also given to Dr. Fred Wiegmann, Dr. J. F. Hudson, and Dr. Gene Sullivan for reviewing the manuscript.

Economic Status of State-Owned Rural Properties Acquired Through Tax Delinquency in Louisiana

FLOYD L. CORTY AND WAYNE D. TAYLOR[1]

Introduction

A property tax is probably the oldest source of public funds for financing state and local governments. In 1961 total property taxes in Louisiana amounted to more than $169 million.[2] Of this amount more than $147 million was designated for financing local services, such as schools, roads, levees, hospitals, and other miscellaneous services. The property tax burden falls upon landowners and there are occasions when some landowners lose title to property because of failure to pay taxes.

Unpaid taxes become delinquent on January 1 of the year following assessment. Tax collectors in each parish are directed by law to give notice that the taxes on the property are delinquent and if the taxes are not paid within 20 days after the notice is issued, the property will be sold at public auction. If the highest bid for the property falls short of an amount equal to the taxes due, plus other costs, the property is then adjudicated to the state. Title to tax adjudicated land remains with the state and cannot be divested by the state for three years following the date of recording state ownership, except through redemption by the delinquent owner.

Tax delinquency in Louisiana has been a perpetual problem, and its magnitude has been inversely correlated with levels of prosperity. Tax delinquency was most prevalent during the depression years of the 1930's. In 1938 more than 2 million acres of land in Louisiana were reported tax delinquent and under state ownership. Records in the State Land Office indicate that about 70 percent of this land is still held by the state. The apparent loss of income to the state due to tax delinquency through 1960 was estimated at $400,000 annually. The additional cost of administering these tax adjudicated lands was estimated at more than $25,000 annually.

A wave of prosperity after World War II somewhat alleviated the problem of tax delinquent lands. Nevertheless, tax delinquency still persists. As of November 1961 there were 814 unredeemed tracts of three acres or more in size which had become tax delinquent since 1938. This amounted to more than 40,000 acres of land with an assessed value of nearly $300,000.[3] In one parish alone 191 tracts, containing a little more than 7,000 acres, were reportedly tax delinquent and listed as state-owned land.

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[1] Associate professor and former graduate assistant, respectively, Department of Agricultural Economics and Agribusiness, Louisiana Agricultural Experiment Station, Louisiana State University, Baton Rouge, Louisiana.

[2] Louisiana Tax Commission, Tenth Biennial Report, 1960-1961.

Purpose of Study

The primary purpose of this study was: (1) to ascertain the extent of and reasons for tax adjudications of rural property, (2) to determine the current status of previously adjudicated land, and (3) to make recommendations designed to improve the administration of tax delinquent properties. Specifically, the following objectives gave direction to the study:

1. To provide information on tax delinquency and tax adjudicated lands for the period 1938 to 1960,
2. To determine if particular areas are disadvantaged by the property tax when comparing farm yields with tax loads,
3. To learn, if possible, why the landowners allowed the land to become tax delinquent,
4. To determine whether a laxity in administering the tax laws is responsible for tax delinquency,
5. To find out how tax adjudicated land is utilized by the state, and what efforts are made to return these lands to private ownership,
6. To determine whether tax delinquency is more prevalent on small uneconomic size units than on larger units,
7. To determine whether tax delinquency is closely associated with absentee ownership, and
8. To see whether tax adjudicated lands held by the state provide more revenues when in this status than when owned by private individuals.

Procedure

Only tracts of three acres or more were considered in this study, thus omitting the many urban lots which account for a considerable proportion of the tax delinquency. Records of tax adjudicated lands, for the period 1938 to 1960, were inspected in the State Land Office to ascertain the extent of tax delinquency, by parishes. In addition, the size, location, and assessed value of each tract and the amount of taxes involved were noted.

A 10 percent random sample of the total number of adjudications was selected for additional study and to this was added all tax adjudications which had occurred since 1950 in the parishes where sample adjudications were located. This addition to the random sample gave

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[3] The multitude of urban and rural lots of less than three acres in size are not included in these totals.

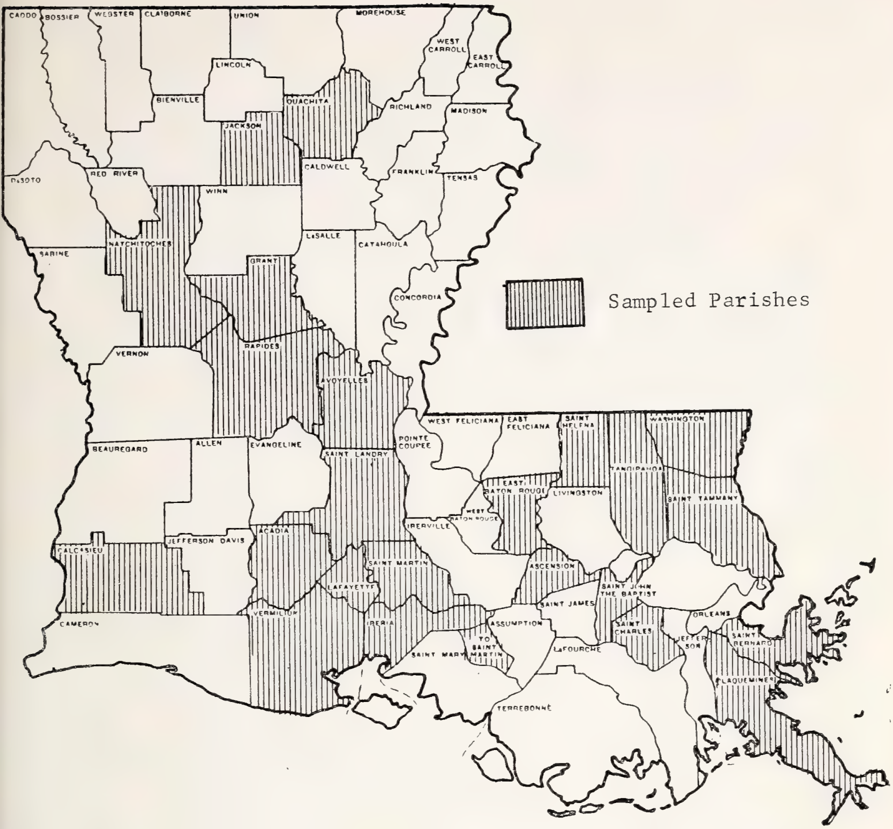

FIGURE 1.—Parishes in which Tax Adjudicated Lands were Sampled, Louisiana, 1938 to 1960.

special emphasis to those parishes having a greater incidence of tax delinquency in recent years and it was felt that the inclusion of more recent adjudications would make it easier to locate and interview former owners of tax adjudicated properties.

The final sample included 139 tracts located in 23 parishes (Figure 1). Each adjudicated tract was investigated thoroughly by reviewing the transfer of ownership in the conveyance records of the respective parishes. In addition, tax assessors, deputies, or clerical assistants in the respective parishes were asked to explain the current status of each adjudicated parcel, and to give the name of the original owner and his current address.

Complete property descriptions and land ownership maps were most essential in locating tracts for this study. Tracts without adequate descriptions were difficult to locate and this fact frequently explained why the tract was adjudicated. The tracts that could be accurately located were visited to observe the type of land and its current use and to note whether it was abandoned or occupied. Whenever possible, the original owners were interviewed or interrogated by mail questionnaires to learn why the land was allowed to become tax delinquent.

Sheriffs, or their deputies, were frequently consulted regarding procedures for disposal of tax adjudicated properties through public sales. Finally, several sales were attended to observe these procedures.

Assessment and Taxation Process

Public utility properties are assessed directly by the Louisiana Tax Commission and these assessments are submitted to the assessors in the appropriate parishes. Public utilities include: oil and gas pipelines, electrical transmission lines, water and gas distribution systems, railways, telegraphs, telephones, sleeping cars, express businesses, interstate and individual watercraft, and commercial airlines.

The responsibility for listing and assessing real property, with the exception of designated properties assessed directly by the Louisiana Tax Commission, is entrusted to the parish assessor.

The assessors are required to have all properties listed and valued by May 1 of each year. Assessments are based on the condition of the property existing on January 1. Assessors are instructed to give notice for 10 days that the listing of the property has been completed, and that the valuations made are in accordance with the law. This notice is to be published in the local newspaper or posted on the courthouse door. The assessment lists are then made available for inspection and correction in the assessor's office for a period of 20 days following expiration of the notice.[4]

Immediately after the tax assessors file the tax rolls, the tax collectors are required to send tax notices by letter or post card to each taxpayer listed. The notice advises the taxpayer that the taxes are due on or before the 31st day of December. Taxes that are unpaid on December 31 bear a penalty of 10 percent per annum from the date of delinquency. Failure of the tax collector to send the notice, or failure of the taxpayer to receive the notice, does not absolve the owner of his tax responsibility, nor does it affect the sale of property for the delinquent taxes.[5] The sheriff of each parish, except the Parish of Orleans, is ex officio tax collector.

As authorized in the Revised Statutes of 1950, Section 2106, tax payments may be deferred in case of overflow, general conflagration, general destruction of crops, or other public calamity in any parish or political subdivision therein. Landowners who wish to have property taxes deferred must make a sworn statement in triplicate to the tax collector on or before December 31 of the year in which the taxes are assessed. Copies of the statement must be signed by the landowner, stating that his land has been damaged or otherwise injured by some calamity. The postponed taxes may be divided into 10 equal parts, and one part is to be paid each year for 10 years.

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[4] Louisiana Revised Statutes of 1950, Title 47, Section 1987.

[5] Louisiana Revised Statutes of 1950, *op. cit.*, Section 2101.

Process of Adjudication and Redemption

On the second day of January each year, or as soon as possible thereafter, the tax collectors notify each delinquent taxpayer, by registered mail, certified mail, or public service, that taxes must be paid within 20 days after date of the notice or the property will be sold. In the case of unknown owners, the tax collectors also publish, once a week for two weeks in official parish newspapers, a description of delinquent properties within those parishes that will be sold for the nonpayment of taxes.[6]

At the expiration of 20 days' notice, the tax collectors advertise the consolidated list of delinquent properties to be sold.[7] The tax sales are to be held on or before the first day of May following the year of assessment, or as soon as possible thereafter.[8] Owners of tax delinquent properties may point out certain portions of the property to be sold for taxes. In case the owner does not designate portions to be sold, the sheriff then sells the least amount of property any bidder will buy for the amount of taxes, interests, and costs. The sale is without appraisement and the property can be redeemed by the former owner or heirs at any time during a three year period from the date of sale.[9] The property can be bought by individuals, or it can default to the state. If there are no bids on the tax delinquent property, the land is then adjudicated to the state.[10]

The title acquired at a tax sale is not completely valid during the three-year period of redemption. However, the purchaser can take possession of the property without judicial proceedings with the consent or acquiescence of the tax debtor, or otherwise, provided there is no violence involved.[11]

The Register of the State Land Office is placed in charge of all properties adjudicated to the state for unpaid taxes. He keeps all records, papers, and documents concerning the acquisition, cancellation, redemptions, and sales of tax adjudicated land.[12]

Owners, heirs, legatees, or creditors may redeem property from the state as long as the title remains with the state. Persons wishing to redeem property adjudicated to the state may do so by paying to the State Treasurer the amount of all taxes, costs, a 5 percent penalty, and an interest rate of 1 percent per month until the property is redeemd. Upon redemption, the Register of the State Land Office will cancel the the records of adjudication in his office and notify the assessors in parishes where the property is located.

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[6] *Ibid.,* Section 2180.

[7] *Ibid.,* Section 2181.

[8] *Ibid.,* Section 2182.

[9] Constitution, *op. cit.,* Section 11, Article X.

[10] Louisiana Revised Statutes, *op. cit.,* Section 2186.

[11] *Ibid.,* Section 2185.

[12] *Ibid.,* Section 2186.

Another method of redeeming property is by paying the Register of the State Land Office the actual cash value of the property in lieu of all taxes, interest, and penalties outstanding. In this instance, the actual cash value is determined by the assessor and the president of the police jury or other governing body in the parish where the property is located, subject to the approval of the police jury and the Louisiana Tax Commission.[13]

Owners of land sold for unpaid taxes can also redeem property from individual purchasers within the three-year period of redemption. The person redeeming the property must pay the purchaser or tax collector all taxes due, interest, costs, and a 5 percent penalty, plus a payment of 1 percent per month until the property is redeemed. In addition the purchaser of the property is entitled to receive the value of improvements made on the property since the tax sale.[14] The value of the improvements is determined by two disinterested persons, appointed by the parties involved. The disinterested persons, acting as appraisers, take an oath before a qualified official to justly value the improvements in question. If the two appointed appraisers disagree, they appoint a third disinterested person, whose evaluation is final.[15]

Adjudication can be cancelled in instances where sales were erroneous, the property dually assessed, or where clerical errors were made in the process of adjudication.[16]

Requests to cancel erroneous tax sales have to be made by the owners or their agents to the Register of the State Land Office. Affidavits must be made setting forth details concerning the erroneous sale and, in the case of dual assessments, evidence must be presented to show who paid taxes on the property for the year of adjudication. The affidavits must be verified by the assessor and the tax collector, and signed by the taxpayer. A cancellation certificate is then issued by the Register and must be recorded in the office of Clerk of Court in the parish.

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[13] *Ibid.,* Section 2224.

[14] *Ibid.,* Section 2222.

[15] *Ibid.,* Section 2223.

[16] *Ibid.,* Section 1991.

Sale of Adjudicated Land

After the three-year period of redemption, any person wishing to purchase property that has been adjudicated to the state for unpaid taxes, can request a sale.[17] A deposit of $35 ($60 in Orleans Parish) must be deposited as evidence of good faith. The Register of the State Land Office then will appoint an appraiser, to be paid from the proceeds of the sale, to appraise the property. A minimum price is established on the basis of the appraisal. It is required that the proposed sale be published in the official journal of the parish 30 days prior to the actual sale. The advertisement must give the description of the property, the time and terms of the sale, and the minimum price which will be accepted.

According to the law, the property is sold by the sheriff of the parish at the principal front door of the courthouse between the hours 11 a.m. and 1 p.m., to the last and highest bidder for cash.

Any moment before the actual sale takes place, the original owner of the tax adjudicated property, his heir, administrator, executor, assign, or successor may in effect stop the sale by paying all taxes, penalties and costs. If the highest bid does not equal or exceed the minimum fixed price, the sheriff will not sell the property. However, upon the receipt of an additional $35 (except in Orleans Parish, which is $60) the Register of the State Land Office will fix a different minimum price at not less than one-half the original minimum price, and readvertise the property for sale.

If the sale is completed, the $35 deposit is returned to the applicant. If there are no bidders and the sale is not made, the advertising costs and the sheriff's fees are deducted, and the remainder is returned to the applicant.

Revenues derived from sales of adjudicated properties are forwarded to the State Treasurer, after a deduction of 4 percent of the sale price for sheriff's fees. The Treasurer finally pays, in order of preference, the following items:

> (1) all taxes, interest, and costs due to the state, parish, municipality, or its agencies at the time of adjudication to the state, (2) taxes, interest, and costs due to the state, parish, municipality, and other agencies subsequent to the date of the sale, and (3) all paving liens or interest due the municipality.

If the proceeds from the sale are insufficient to pay the amounts previously listed, the purchaser is burdened with the obligation to pay the deficiency. The remainder, if any, is credited to the State General Fund.

The state does not warrant the titles of tax adjudicated land offered for public sale. Therefore, it is very important that the prospective purchaser of a particular tract determine the validity of the title as

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[17] *Ibid.*, Section 2189.

TABLE 1.—Property of Three Acres or More Adjudicated since 1938 and Remaining Unredeemed November 1961, by Parishes

Parish	Number of tracts	Total acres	Assessed value	Taxes due
Acadia	3	20.57	$ 400.00	$ 22.29
Allen	2	80.00	240.00	19.50
Ascension	4	112.32	890.00	53.85
Assumption	4	485.00	960.00	. . . .
Avoyelles	191	7,189.67	91,727.00	4,744.37
Beauregard	. .	.	. . .	. . . .
Bienville	11	286.50	2,000.00	116.57
Bossier	. .	. . . .		. . . .
Caddo	3	85.00	450.00	23.15
Calcasieu	19	252.10	1,230.00	157.21
Caldwell	. .	. . . .	. . . .	. . . .
Cameron	.	. .	.	. . . .
Catahoula	1	40.00	120.00	10.65
Claiborne	. .	. . . .	. . . .	. . . .
Concordia	. .	. . . .	. . . .	. . . .
DeSoto	4	35.00	328.00	131.42
East Baton Rouge	15	527.98	6,700.00	191.40
East Carroll	1	4.23	29.00	7.61
East Feliciana	2	156.00	1,000.00	39.08
Evangeline	7	76.00	870.00	47.52
Franklin	.			. .
Grant	4	84.00	280.00	31.17
Iberia	22	671.06	14,670.00	729.67
Iberville	1	7.50	300.00	12.34
Jackson	4	82.60	355.00	36.71
Jefferson	. .	. .	. . . .	. . . .
Jefferson Davis	1	10.00	4,800.00	173.98
Lafayette	14	295.00	8,060.00	304.19
Lafourche	. .	. . . .	. . . .	. . . .
LaSalle	. .	. . . .	. . . .	. . . .
Lincoln	1	20.00	90.00	7.85
Livingston	20	547.45	4,300.00	367.56
Madison	. .	. . . .	. . . .	. . . .
Morehouse	. .	. . . .	. . . .	. . .
Natchitoches	11	377.00	2,950.00	130.78
Ouachita	7	183.00	1,240.00	53.01
Plaquemines	35	8,504.60	25,829.00	793.25
Pointe Coupee	1	10.00	20.00	17.82
Rapides	58	2,594.41	19,669.00	997.63
Red River	3	168.00	920.00	51.24
Richland	2	12.84	200.00	21.42
Sabine	1	40.00	160.00	15.29
St. Bernard	65	6,530.00	9,540.00	2,018.54
St. Charles	8	101.43	9,720.00	306.00
St. Helena	23	786.00	4,966.00	358.30
St. James	. .	. . . .	. . . .	. . . .
St. John the Baptist	18	392.00	13,655.00	411.23
St. Landry	17	474.87	6,470.00	321.18
St. Martin	25	1,064.13	4,000.00	321.60

(Continued)

TABLE 1 (Continued)

Parish	Number of tracts	Total acres	Assessed value	Taxes due
St. Mary	2	173.52	660.00	20.74
St. Tammany	75	3,374.02	17,800.00	1,171.73
Tangipahoa	63	1,769.82	16,840.00	979.81
Tensas	1	4.00	40.00	7.65
Terrebonne	1	279.00	420.00	8.41
Union	3	140.00	700.00	36.77
Vermilion	25	715.14	6,945.00	385.89
Vernon	1	11.50	90.00	14.74
Washington	34	1,413.05	7,370.00	287.92
Webster	. .	. . . .	. . . .	. . . .
West Baton Rouge	. . . .	. . . .	. . . .	. . . .
West Carroll	. .	. . . .	. . . .	. . . .
West Feliciana	1	320.00	960.00	29.51
Winn	. .	. . . .	. . . .	. . . .
TOTAL	814	40,186.31	$291,025.94	$16,036.61

Source: Figures compiled from records in the State Land Office.

held by the state. The state reserves all mineral rights of tax adjudicated property sold. Sales in the parish of Orleans are scheduled on Fridays; Beauregard, Caldwell, Claiborne, DeSoto, Red River, St. Helena, Union, and Washington Parish sales are scheduled on Saturdays; and sales in all other parishes are scheduled on Wednesdays.

Extent of Adjudications

Adjudications Prior to 1938

During the period 1880 through 1937, a total of 2,045,783 acres of land was adjudicated to the state for nonpayment of property taxes.[18] Tax delinquent land was reported in all parishes, and the total assessed value of the 24,655 tracts amounted to more than $14 million. The average tract size was 83 acres. More than $652,000 in aggregate property tax revenues was represented by these adjudicated properties.

The adjudications, however, were concentrated within specific parishes. Ten parishes accounted for 62 percent of the total tax adjudicated land. These were Avoyelles, Tangipahoa, Natchitoches, Plaquemines, Rapides, St. Martin, Bienville, Calcasieu, St. Tammany, and St. Landry. In fact, approximately one-fifth of their total land areas was tax delinquent in 1937.[19]

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[18] J. P. Montgomery, "Louisiana Tax Reverted Land and What Could Be Done About It," *Second Progress Report of the Louisiana State Planning Commission,* (Baton Rouge, Louisiana; June 3, 1940), pp. 47-74.

[19] *Ibid.,* p. 52.

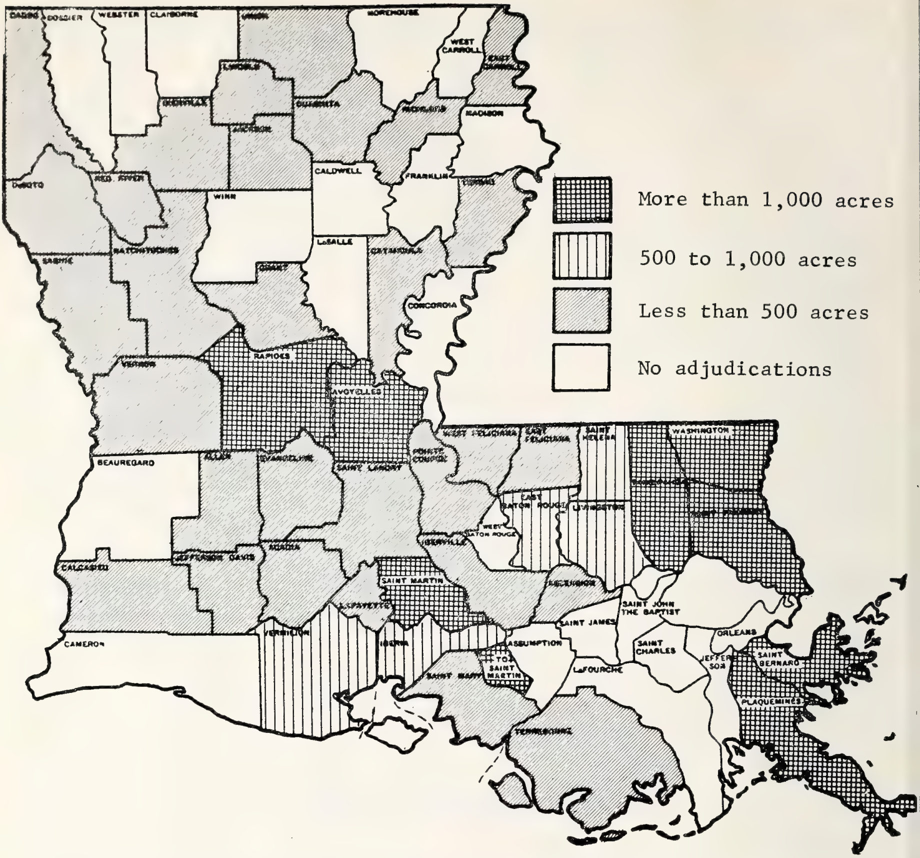

FIGURE 2.—Extent of Total Tax Adjudications, by Parishes, Louisiana, 1938 to 1960.

Adjudications from 1938 to 1960

Findings of the present study indicate that 814 tracts, three acres or more in size, in 46 parishes were adjudicated to the state for nonpayment of property taxes from 1938 to 1960, and are still unredeemed or unsold (Figure 2). Adjudications by parishes from 1938 to 1960 are shown in Table 1. More than 40,000 acres of land were listed as being state-owned through defaults in tax payments. The assessed value amounted to more than $291,000 with the sum of taxes due amounting to little more than $16,000.

Over 75 percent of the adjudications occurred during the first five years of this period (Table 2). More than one-third of the adjudicated tracts ranged from 3 to 10 acres in size, and 65 percent were 30 acres or smaller (Table 3).

TABLE 2.—Number of Adjudicated Tracts, Three Acres or More in Size, by Years, and Percentage of Total

Year	Number of tracts	Percent of total
1938	119	14.6
1939	190	23.3
1940	122	14.9
1941	101	12.4
1942	89	10.9
1943	33	4.0
1944	26	3.1
1945	17	2.0
1946	7	0.8
1947	23	2.8
1948	13	1.5
1949	11	1.3
1950	9	1.1
1951	7	0.8
1952	5	0.6
1953	10	1.2
1954	8	0.9
1955	8	0.9
1956	3	0.3
1957	4	0.4
1958	4	0.4
1959	5	0.6
TOTAL	814	100.0

TABLE 3.—Frequency Distribution by Size of Tract Adjudicated Since 1938 and Remaining Unredeemed in 1960

Acres in tracts	Number of tracts	Percent of total
3- 10	318	39.0
11- 20	145	17.8
21- 30	73	8.9
31- 40	100	12.2
41- 50	32	3.9
51-100	71	8.7
101-150	15	1.8
151-200	23	2.8
201-250	7	0.8
251-300	5	0.6
301-350	5	0.6
351 and over	20	2.4
TOTAL	814	100.0

Validity of Adjudications

Findings in the study indicate that the sample of adjudicated tracts can logically be divided into two categories; namely, (1) valid adjudications and (2) questionable adjudications. Valid adjudications include those properties which are identifiable and, based on research evidence, appear to be legally owned by the state.

Only 12 tracts in the sample, or 8 percent of the tracts, were apparently valid adjudications. Four of these consisted of marshy lands and were located in one parish. According to the parish assessor, the former owners bought the property for investment purposes from a large land company. At the time of the purchase, the buyers were of the opinion that mineral leasing was active in the area. When it became apparent that mineral activity would not develop, the landowners stopped paying the property taxes. A title search indicated that these tracts were identifiable and had been adjudicated because of tax delinquency.

Four other tracts located in separate parishes were not shown on ownership maps and could not be identified for visual inspection but had adequate title descriptions for survey purposes. In each case the assessors and tax collectors did not know the addresses of the original owners. The other four identifiable tracts in the sample were redeemed during the course of this study by heirs or wives of former owners.

Questionable adjudications include properties with inadequate or incorrect title descriptions, those taxed but unredeemed, and those with disputed ownership. About 127 tracts, or 92 percent of the adjudications in the sample, fell into this category (Table 4).

Inadequate Title Descriptions

For many years, parishes in South Central Louisiana have used the metes and bounds system of describing property. Although the present trend favors the rectangular survey system, one parish still uses the system of metes and bounds exclusively.

Fifty of the 139 tracts in the sample, or about 36 percent, could not be located because of inadequate property descriptions. Thirty of these unlocated tracts were described only by naming bordering landowners. Tracts with this type of description become lost when the ownership of the bordering land is transferred, and the problem is magnified over time. The following examples are typical of some inadequately described properties:

1. Rosalie Vincent, 34 acres — N. by Broussard, South by Vincent, Ward 8, Adjudicated 1939.
2. Mrs. Williamson Simmons, 11 acres, N. — bayou, S & E Bowman, W. — Couvillion, Adjudicated 1953.
3. Sully P. Rabalias, 25 acres, N. — Remi Bordelon, S. — A. J. Bordelon, E. — H. Bordelon, W. — H. O. Moreau, Ward 6, Adjudicated in 1939.

TABLE 4.—Classification of the Sample of Tax Adjudicated Properties, Louisiana, 1938 to 1960

Classification	Number of tracts	Percent of total
Valid Adjudications	12	8
Questionable Adjudications		
Inadequate Title Descriptions	50	36
Adjudications Due to Clerical Errors	39	28
Adjudicated Tracts That are Taxed but Unredeemed	30	22
Disputed Ownership	8	6
TOTAL	139	100

4. M. Tassin, 40 acres, N. — Joffrion, S. — Unknown, W. — Dufore, E. — Public Lane.

Twenty of the tracts, although based on the rectangular land survey system, were not located because the descriptions were incomplete. The following examples demonstrate the problem:

1. 3 acres in Section 33, Township 7, Range 11, Ward 3, Adjudicated 1939.
2. 14.67 acres in Section 32, Township 6, Range 1 West, Adjudicated in 1942.
3. 5.22 acres in Section 7, Township 2 South, Range 3 East.

In these instances, the descriptions were inadequate because a section contains 640 acres and without some point of reference within the section, it is impossible to locate these relatively small tracts. Ownership maps, showing the location of tracts within a section, would be helpful but very few parishes have up-to-date ownership maps. One parish did not have ownership maps of any kind.

Assessors were generally of the opinion that many of the adjudicated tracts were actually on the tax rolls and in good standing, although they were listed as adjudicated in the records of the State Land Office. However, determining whether these tracts were truly adjudicated or currently on the tax rolls would probably require a complete land survey of the area in question, and the construction of up-to-date ownership maps.

Adjudications Due to Clerical Errors

Of the 139 tracts in the sample, 39 tracts (28 percent of the adjudications) were due to clerical errors which resulted in dual assessments or erroneous property descriptions. Eighteen of these tracts were found to be dually assessed. Dual assessments occur when a single tract is listed under different names in two places on the assessment rolls. The following example indicates how property can become tax adjudicated because of dual assessment:[20]

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[20] Names were omitted in this portion of the report to avoid offending unsuspecting landowners.

A 40 acre tract located in the SE¼ of SE¼ of Section 12, Township 2 South, Range 3 East, was assessed to Mr. H. At the same time the property, identically described, was assessed to Mr. R. who is presently paying taxes. The property was presumed tax delinquent in the name of Mr. H. and was subsequently adjudicated to the State for nonpayment of property taxes.

Twenty-one tracts had errors in the property descriptions. The following are examples:

1. A tract containing 60 acres was adjudicated in the name of Mr. D. in 1951. The property was described as being located in the S½ of SE¼ of Section 48, Township 7 South, Range 8 East. Further investigation indicated that Township 7 South, Range 8 East did not contain a section numbered 48. Furthermore the acquisition of the land by Mr. D. could not be found in the conveyance records in the Clerk of Court's Office.
2. In another instance, a 35 acre tract adjudicated in 1953 was in Section 46, Township 1 South, Range 2 East. A careful investigation failed to locate the property. In fact, there was no Township 1 South, Range 2 East within the boundaries of the parish in which the adjudication was reported.
3. Another tract containing 10 acres, described as the S½ of S½ of SE¼ of NW¼ of Section 28, Township 5, Range 11 East was adjudicated in the name of Mrs. T. in 1939. A search of conveyance records revealed that the owner did not own land in Section 28, but in Section 8, Township 2, Range 11 East. The property had been transferred several times since 1939 and apparently the necessary taxes were being paid regularly.

Adjudicated Tracts that are Taxed but Unredeemed

At least 30 tracts listed as state-owned land, or 22 percent of the sample, were currently on the tax rolls with taxes being paid by someone considering himself the legitimate owner. Twenty of these adjudications occurred as a result of a change of ownership. In most instances, the property was adjudicated in the name of the vendor (seller) in the year in which the property was transferred, as indicated by the following examples:

1. One tract containing 5 acres owned by Mrs. A. was adjudicated in 1959. However, Mrs. A. had sold the property to Mr. E., et. al., August 5, 1959. In 1960 the property was on the assessment roll assessed to Mr. E., et. al., and the taxes were paid.
2. Another tract of 80 acres was adjudicated to the state in the name of Mr. B. for taxes due in 1940. However, Mr. B. had sold the property to Mr. F. November 18, 1940. Mr. F., in turn, sold the property to Mr. P. December 13, 1940.

Mr. P. is now assessed with the property and the taxes are being paid. Yet, this property is still considered tax adjudicated and owned by the state.

As shown in these examples, the present landowners were careless about clearing up delinquent taxes at time of the purchase, and assessors failed to reconcile the records to show a sale and a purchase of the same property. The purchasers probably assumed that the taxes were paid, especially if the sale occurred in the latter part of the year. Delinquent tax notices were probably sent to the original owners and they evidently disregarded the delinqunt tax notices since they no longer owned the property. The purchasers, on the other hand, are immediately listed on the new assessment rolls and commence paying taxes on tax adjudicated, or state-owned land.

Eight of these tracts were adjudicated to the state in the name of the original owners, but the properties reappeared on the tax rolls in their names in later years. Hence, the former owners are paying taxes on properties that were not redeemed and are still considered state-owned. For example:

1. Mrs. G. received 3.56 acres through a partition June 30, 1942. In 1943 the property was adjudicated to the state in her name. The property has been assessessed to her since that time, and the taxes have been paid annually. A certificate of redemption could not be found in the parish records.
2. A tract containing 5 acres was purchased by Mrs. P. from Mr. G. in 1941. The next year the property was adjudicated to the state. Mrs. P., however, has been assessed with the property since the year following the adjudication and the taxes have been paid continuously.

Finally, two of these tracts are currently enjoying tax exemptions under the homestead exemption provisions and taxes are being paid through the State Property Tax Relief Fund. Redemption certificates, however, could not be found in either case.

Disputed Ownership

Eight adjudicated tracts in the sample had questionable titles. A title search revealed that all these tracts were bought and then allowed to revert to the state when there appeared to be a questionable title.

In one parish an individual would buy, for investment purposes, all properties that were sold for delinquent taxes. If, after purchase, the title was found to be unsound, he would allow the tract to revert to the state for delinquent taxes.

Landowners' Explanations

Sixteen landowners were interviewed concerning tax adjudicated properties. Seven persons were original owners, three were relatives, five thought they were the new owners, and one was a neighboring landowner.

Four of the original owners interviewed were unaware that their properties had been adjudicated to the state for nonpayment of property taxes. For example:

1. Two landowners had tracts adjudicated to the state in 1939. They were unaware that the land had been adjudicated to the state for nonpayment of property taxes. Neither landowner remembered receiving a delinquent tax notice. Both were making regular tax payments on other properties in the parish. Consequently, they assumed that the taxes that were paid regularly included the taxes levied on the adjudicated properties.
2. One former landowner acquired 80 acres of pasture land at a tax sale in 1956. In 1958 the land was adjudicated to the state in his name. He was unaware of the tax adjudication and had sold the property to another party between 1956 and 1958. He was sure that the other party had a good deed to the land, and that the present taxes were being paid.
3. Another former landowner had about 5 acres adjudicated to the state in 1941. The former owner had sold the property to the present owner May 9, 1940. The respondent was unable to recall receiving a delinquent tax notice, and had no idea that the property was tax delinquent. The present landowner has paid the necessary property taxes since the date of purchase.

Three former landowners knew of the tax deliquency and tax adjudications and gave the following reasons for allowing the property to become tax adjudicated:

1. One elderly landowner received a 20 acre tract in a partition in 1958, described as the S½ of SW¼ of SW¼ of Section 14, Township 5 North, Range 1 West. The land was then placed on the assessment list in her name. About a year later, the tract as described above was located and visited. The property as described contained residents who had occupied the land for several years, and the homesteader's claims appeared to be valid. Therefore, the respondent refrained from paying property taxes, assuming that her title was invalid.
2. In 1955 a tract containing 40 acres was purchased for $7,500 by two persons in partnership. The property was then placed on the assessment roll in their names. However the same property is also assessed to a corporation, that has been paying the taxes for years. According to the respondents, the taxes were not paid because the title was unsound. Consequently, the tract was adjudicated to the state in the partners' names. The actual ownership of the property is presently being decided by the civil courts.

3. Another landowner was assessed with a 60 acre tract that was formerly owned by her father. She allowed the property taxes to become delinquent when she was advised by the tax collector that the title was unsound. However, a local farmer had previously leased the land and agreed to pay the taxes on the property in her name and deduct the amount from the lease payments. When interviewed, the farmer produced tax receipts indicating that the property taxes were paid.

Based on interviews with persons who thought they were the owners of tax adjudicated properties, it was evident that the five following adjudications were unquestionably erroneous.

1. A 20 acre tract was adjudicated in the name of John R. Reed in 1939. However, the ownership map indicated that a Mr. W. presently owns the property. A title search and interview with Mr. W. indicated that a John R. Reed had never owned the property.
2. Another tract containing 125 acres was adjudicated in the name of J. U. Guillot in 1938. According to the ownership map, the property is presently owned by a Mr. C. According to Mr. C., he could not recall a person by that name who owned property in that area. Mr. C. had lived in the area for about 60 years and had paid taxes on the property regularly.
3. A tract containing 80 acres was adjudicated in 1945, and was listed on the assessment rolls as an unknown owner. The tract was described as the W½ of NE¼ Section 17, Township 1 North, Range 7 East. The owner as indicated on the ownership map stated that he and his family had owned the property all their lives and he was sure that the property taxes had never been delinquent. Assessment rolls in the parish were checked back to 1938 and the property taxes had been paid since that time.
4. A tract containing 40 acres was adjudicated in 1950 in the name of Mr. P. According to the records Mr. P. had purchased the property at a tax sale July 9, 1949. The property was then adjudicated in 1950 in Mr. P.'s name. Mr. P was interviewed and stated that he had never owned the tract. Inquiry was made in the general area where the property was located and other persons with the same name or a similar name could not be found. According to the ownership maps, the property was included in a large tract that had not been tax delinquent.
5. In 1940 a tract containing 20 acres was adjudicated in the name of Mrs. S. Some discrepancies were found in the description of the property. According to the property ownership map, Mr. Smith is the present owner. According to the response given by Mr. Smith, he bought the property in

1939, and the taxes have been paid regularly. Also, Mrs. S. was not known to have owned land in the area.

When the original owners could not be contacted, relatives, heirs, or neighbors were interviewed. From these, the following explanations were offered:

1. A tract containing 100 acres was adjudicated in 1940. According to an heir, tax delinquency had resulted from an overload of debt. The heir knew that the property was "lost," but was *not* aware that the property could be redeemed. In addition, the property was described by naming the bordering landowners; consequently, the heir was unsure of the exact location of the tract.
2. A relative living on a three acre tract that had been adjudicated to the state, could not explain why the land had become tax delinquent. However, at the present time, the tract is exempt from property taxes because of homestead exemption provisions. The tract appeared on the assessment rolls in the original owner's name. A certificate of redemption could not be found in the Clerk of Court's records, or records at the State Land Office.
3. A tract containing 160 acres was adjudicated in 1948. According to an heir, the original owner had refrained from paying property taxes because of an unsound title. The property is now assessed to a lumber company and the taxes have been paid since 1948. However, after a thorough search of parish conveyance records, a record of acquisition of the property by the lumber company could not be found.
4. A tract containing six acres was tax delinquent and adjudicated to the state in 1940. When the tract was located and visited, it was learned that the property did not contain residents. A neighboring landowner was interviewed to determine why the tract had become tax delinquent. He reported that the former owner had died and heirs to the property were all living in distant places. Evidently the heirs either did not know the land was tax delinquent, or they were not interested in redeeming the land.

Assessors generally recognize that most of the adjudications are erroneous and could be erased from the records if new land surveys were run on questionable tracts and land ownership maps brought up the date. The high number of adjudications in one parish was believed to be due to irregular land manipulations by real estate speculators. In the past, newly surveyed tracts appeared on the rolls but were allowed to become tax adjudicated when the illegal ownership was disputed. It appears that the taxes on these tracts have been paid continuously by the legitimate owners. Several assessors cited examples of properties being subdivided, transferred, and financed by lending institutions even though these lands were legally adjudicated to the state. They also expressed opinions to the effect that various Notary Publics were lax in getting accurate property descriptions from the vendors during transfer of ownership.

Concentrations of Adjudications

Tax delinquency and adjudications seemed to be particularly concentrated in eight parishes. Each had more than 1,000 acres of land adjudicated during the period 1938 to 1960. These eight parishes, namely, Avoyelles, Rapides, Plaquemines, St. Bernard, St. Martin, St. Tammany, Tangipahoa, and Washington, accounted for 67 percent of the adjudications within the state during this period.

Two parishes, Plaquemines and St. Bernard, had unusually large tracts adjudicated. The average size was 243 acres and 100 acres respectively. These large tracts included marshy areas that produced little or no income. In fact, about 90-95 percent of the tracts adjudicated to the state in these two parishes are classed as marsh land. Tax loads for these adjudicated lands from 1938-1944 averaged about $.09 per acre in Plaquemines Parish and $.30 per acre in St. Bernard Parish.[21] Interestingly, neither parish had adjudications after 1944, indicating that tax delinquency stopped after possibilities of oil exploration became apparent. The other six parishes continued to have adjudications throughout the period 1938 to 1960. The average size of adjudicated tracts for these six parishes ranged from 28 acres in Tangipahoa Parish to 45 acres in Rapides and St. Tammany parishes.

Relationship of Tax Loads to Farm Income

Since 1940, taxes levied on farm real estate have remained below the per acre average for the United States, as shown in Table 5. Nevertheless, since 1938 six parishes have had a chronic problem of property adjudications. These parishes are: Avoyelles, Rapides, St. Martin, St. Tammany, Tangipahoa, and Washington.

In an attempt to determine whether the high incidence of tax adjudications was due to excessive tax loads relative to farm income, taxes per acre and farm income per acre for this group of parishes were

TABLE 5.—Taxes Levied on Farm Real Estate in Louisiana, Compared With U. S. Average, Selected Years 1930-1961

	1930	1935	1940	1945	1950	1955	1959	1960	1961
				(Dollars Per Acre)					
U. S.	0.57	0.37	0.40	0.44	0.69	0.88	1.13	1.22	1.30
La.	0.57	0.45	0.31	0.33	0.40	0.50	0.62	0.60	0.62

Source: U.S.D.A., Economic Research Service, "Farm Real Estate Taxes—Recent Trends and Developments," October 1962, pp. 2, 7.

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[21] Based on data compiled from the State Land Office, contained in Table 1.

TABLE 6.—Gross Receipts per Acre, Tax per Acre, and Taxes as a Percent of Gross Income, Two Groups of Louisiana Parishes, 1940

Parish	Gross receipts per acre	Average tax per acre[1]	Taxes as a percent of gross income
	Group I—High Rate of Adjudications		
Avoyelles	$11.98	$0.40	3.3
Rapides	9.96	0.23	2.3
St. Martin	12.86	0.65	5.0
St. Tammany	4.28	0.21	4.9
Tangipahoa	15.18	0.26	1.7
Washington	4.78	0.22	4.6
Average	$ 9.84	$0.32	3.6
	Group II—No Adjudications		
Beauregard	$ 4.85	$0.15	3.1
Bossier	8.81	0.29	3.3
Caldwell	5.26	0.30	5.7
Cameron	8.77	0.45	5.1
Claiborne	3.97	0.25	6.3
Concordia	4.89	0.16	3.3
Franklin	10.05	0.84	8.4
Jefferson	85.81	1.48	1.7
Lafourche	7.54	0.59	7.8
La Salle	4.32	0.13	3.0
Madison	8.42	0.22	2.6
Morehouse	8.46	0.26	3.1
St. James	18.16	0.36	1.9
Webster	4.32	0.27	6.3
West Baton Rouge	16.42	0.36	2.2
West Carroll	9.26	0.35	3.8
Winn	3.86	0.18	4.6
Average	$12.54	$0.39	4.2

[1] The amount of tax was determined by multiplying the millage rates derived from the 1940 tax assessment roll by the assessed values of all agricultural land reported in the 1940 Tax Commission bulletin. Marsh lands were excluded.

Sources: Louisiana Tax Commission, *Twenty-fourth Annual Report,* 1940, pp. 155-272.

U. S. Census of Agriculture 1945, *Louisiana—Statistics for Parishes,* (U. S. Government Printing Office, Washington, D. C., 1946), pp. 18-31, 44-56.

compared with taxes and farm income for a group of 17 other parishes that had no adjudications since 1938.

The average gross receipts per acre, and taxes per acre, were higher for the group of parishes having no adjudications; and the taxes, as a percent of gross income, were also higher than for the problem parishes (Table 6).

In Group II, Jefferson Parish had an unusually high gross income and tax levy per acre, thus having a considerable upward influence on the average for the group. Nevertheless, a statistical test reveals that the difference between the average tax per acre for the two groups of parishes was not significant at the 5 percent level of probability.[22] Furthermore, taxes were a larger percent of gross income in the group of parishes having no adjudications than in those having a high rate of adjudications.

Summary

This study was designed to determine the extent of rural tax delinquency, the current status of tax adjudicated lands in Louisiana, the causes of these adjudications, and to make recommendations that may help alleviate the problem.

According to records in the State Land Office, more than 24,000 tracts of rural land, containing more than 2 million acres, were adjudicated during the period 1880-1937. From 1938 to 1960, 814 additional tracts (3 acres or more in size) with more than 40,000 acres of land were adjudicated to the state. Most of the adjudicated tracts were relatively small. The average size, since 1938, was 49 acres with about 65 percent of the tracts containing 30 acres or less.

Officials in the State Land Office estimate that about 70 percent of all adjudicated tracts remain unredeemed or unsold. Based on this estimate, the state currently has title to approximately 15,000 tax adjudicated rural tracts, amounting to more than 1 million acres.

It was apparent throughout this study that the number of adjudications was not the result of an oppressive tax load, but more likely the result of clerical errors or laxity in the administration of the property tax. Only 12 tracts out of the sample of 139, were found to be valid adjudications. Thus, more than 90 percent of the adjudications may be considered questionable. About one-third of the tracts could not be located because of inadequate property descriptions. Approximately one-fourth of the adjudications resulted from clerical errors. These errors usually consisted of dual assessments or inaccurate property descriptions. Most of the adjudications occurred as the result of a transfer of ownership.

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[22] $H_0\colon \bar{X}_1 - \bar{X}_2 = 0$

$$\text{Test: } \frac{\text{Difference between means}}{\text{Standard error of diff. between means}} = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\dfrac{(\Sigma X_1^2 + \Sigma X_2^2)\ (n_1 + n_2)}{n_1\, n_2\ (n_1 + n_2 - 2)}}}$$

$$\frac{0.3283 - 0.3905}{\sqrt{\dfrac{0.1487 + 1.472\ (6 + 17)}{6 \times 17\ (6 + 17 - 2)}}} = 0.494 \text{ calculated ``T''}$$

2.080 tabular T at 5% level of probability

$\therefore H_0\colon \bar{X}_1 - \bar{X}_2 = 0$ was accepted

Conclusions and Recommendations

Landowners were, in most cases, unaware of tax delinquencies and tax adjudications. The only time a landowner knowingly permitted his land to become tax delinquent was when the ownership was in dispute, or when the property was obtained under false pretenses.

Absentee ownership apparently did not contribute to tax delinquency. Only about 2 percent of the tracts had absentee owners at the time the property became tax delinquent and adjudicated to the state.

About 90 percent of the adjudicated properties are of a questionable nature and may be considered phantom properties.

It was apparent throughout this study that adjudications were not the result of oppressive tax loads but rather the result of faulty administrative procedures. Furthermore, the adjudications were concentrated in only a few parishes which would indicate weaknesses in the system in those parishes.

It has been estimated that the cost to the state for administering tax adjudicated land is well in excess of $25,000 per year. This is an unnecessary expense that could be reduced by removing the erroneous adjudications from the records.

Lands acquired by the state through tax delinquency are not utilized by the state for any productive purpose, although they may yield some revenue when sold by the state.

A land management program was started by the State Land Office in 1960, in an attempt to solve the problem of erroneous adjudications. It is designed to: (1) clarify and remove erroneous adjudications from the records; and (2) identify lands having clear titles so that they may be easily sold or redeemed. Thus far, the program has resulted in substantial increases in redemptions, sales, and cancellations.

Preliminary investigations also indicate that approximately 70 percent of the titles of identifiable tax adjudicated properties are not clearly vested in the state.

The following suggestions are offered as measures for alleviating the problem of erroneous adjudications:

1. Up-to-date ownership maps could very effectively clarify the status of tax adjudicated properties. The Louisiana Tax Commission should require assessors to keep accurate, up-to-date, ownership maps. Periodic checks to assure compliance should be made by the Tax Commission.
2. Tax collectors, or the State Land Office, should be required to determine the validity of titles of the various tax delinquent tracts before advertising these tracts for sale. If the property descriptions are inadequate, the property should be surveyed before it is advertised for sale. The state should not be a party to an illegal transaction.
3. Property owners are urged to review their property descrip-

tions to ascertain the validity of the description. If the description is incomplete, a survey would be advisable.

4. Landowners need to be informed about tax procedures, adjudications, and the need for clear property titles. The Agricultural Extension Service could perform a valuable service by distributing information and counselling landowners concerning these matters.

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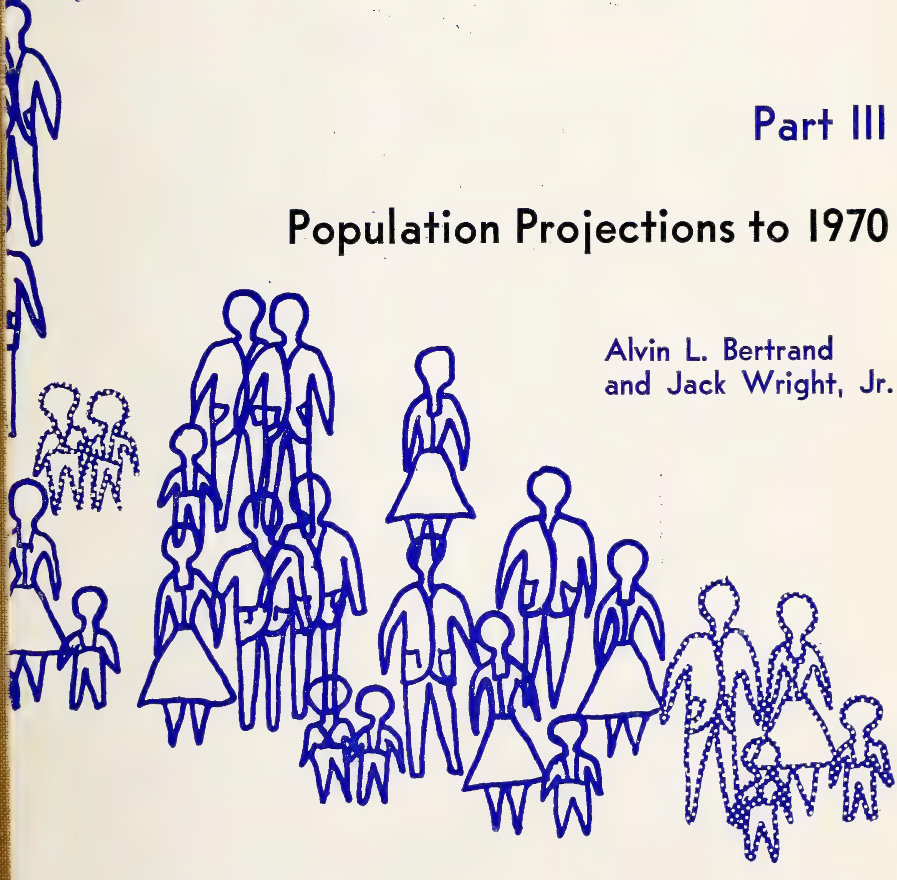
louisiana's human resources

Part III

Population Projections to 1970

Alvin L. Bertrand
and Jack Wright, Jr.



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Louisiana's Human Resources

Part III: Population Projections to 1970

ALVIN L. BERTRAND AND JACK WRIGHT, JR.
Department of Rural Sociology

This study of the future population of Louisiana is the third in a series of publications on Louisiana's human resources to be done by the Department of Rural Sociology, Louisiana State University.[1] It was undertaken in an attempt to provide the many persons and agencies who must plan for the future of the state with a reasonably sound basis for vital decisions relating to the state's human resources.

Problems, Assumptions, and Methodology

Over the years a variety of techniques of population projections have been developed. However, to date, no exact method has been developed which can be used to predict future changes in population with a consistently high degree of accuracy.[2] *The reader is, therefore, cautioned to read the following discussion of methodology carefully and to interpret the population projections made in the light of this discussion.*

The first methodological note may be introduced as follows. Demographers must explain the changes in numbers of people in terms of three variables: births, deaths, and migration. Of these three, births and migration are usually the hardest to predict. With regards to the former, the rapid rate at which the birth rate has changed in past years has been the chief reason for substantial errors in U. S. population projections. The U. S. experiences little external migration at the national level, but there is a constant redistribution of population among and within the states, which adds to the problem of estimating the future population of a given state and its political subdivisions. Although mortality, as mentioned, is generally more constant, an occasional epidemic or other disaster, such as a hurricane or flood, can make this the most important variable affecting the future population growth of a local area.

Since it is difficult to correctly predict births, deaths, and migration, the demographer must prepare and report his projections and forecasts of population changes in terms of certain basic assumptions. Assumptions, of course, are not unique to this analysis, but are also the basis for the preparation of scientific estimates in any field of endeavor. The estimates of the researchers can be considered valid only so long as the conditions in the assumptions are met and *not* otherwise. The projections utilized in this study are based on the following primary assumptions:

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[1] Alvin L. Bertrand, *Louisiana's Human Resources, Part I: Number, Distribution, and Composition of the Population, 1960;* Louisiana Agricultural Experiment Station Bulletin No. 548, November 1961; and Lee Taylor and Arthur R. Jones, Jr., *Louisiana's Human Resources, Part II: Agribusiness and the Labor Force,* Louisiana Agricultural Experiment Station Bulletin No. 562, February 1963.

[2] Meyer Zitter, "Population Projections for Local Areas," *Public Works Publications* (Ridgewood, New Jersey: June 1957).

(1) Economic conditions in the state will remain fundamentally at the level existent in the past decade. Slight variations could occur without invalidating the projections but a severe depression or an unforeseen "boom" would require a complete revision of the estimates.

(2) Residents of the state will not be involved in major catastrophies such as war, which would drastically affect movement of population in and out of the state.

(3) Fertility and mortality rates within the state will follow trends established from 1950 to 1960.

(4) Internal (within the state) and external (outside the state) migration rates will continue at 1950-1960 levels and redistribution of the state's population will follow past trends.

The writers are well aware that the conditions assumed may not be realized. To this extent, their projections will be off. However, present indications (1964) are that population change in the state will continue in a manner similar to that which has occurred in the recent past. In this regard, errors of projection tend to increase almost directly as: (1) the length of the projection increases, and (2) the population size decreases. Therefore, greater reliability should be obtained for the next few years and for the state as a whole, rather than for the cities and parishes of the state. With regards to the latter, it is already evident that the Michoud operation (a government-sponsored space program facility) will affect the future population of the southeastern part of the state.

All analytical models which are used in the computation of population projections are basically self-contained, i.e., they include built-in consideration of historical events. This is true because even with unlimited resources, it is beyond the skill and knowledge of the most dedicated social scientist to identify and evaluate more than a small number of the great variety of factors which could affect population trends. Three major types of population projection techniques are currently in use, including: (1) mathematical methods which make use solely of past trends in total population of the given area, (2) demographic methods which analyze various components of the population, such as fertility, mortality, and migration separately in an effort to account for important variables in age, sex, and other factors, (3) miscellaneous techniques, which use data symptomatic of future population changes such as economic fluctuations.

It is interesting to note that some demographers make a clear distinction between "projections" and "forecasts" on the basis of the techniques used. Projections are said to emanate solely from demographic information, including known birth, death, and migration rates. Forecasts, on the other hand, introduce certain of the more tangible social and economic variables, such as those associated with economic cycles, religious culture, and national policies and trends.[3] In practice, the line between what is a projection and what is a forecast becomes nebulous indeed. The writers use the former term simply because of its technical connotation.

All three of the methods cited above were reviewed in an attempt to select the technique best suited to the purposes and resource limitations of the present study. A decision was made to use the simple mathematical model which has been referred to as the arithmetic method. This technique was selected because of three major considerations: (1) Study has shown the arithmetic method to yield results which are reasonably valid and often as accurate as more complicated methods.[4] (2) The necessary computations can be made from readily accessible data. (3) The computation time needed is considerably less than for most other techniques.[5]

The arithmetic method assumes that persons will be added to a given population at the same rate as has been true in the past. In other words, change is assumed to take place in the form of a straight line throughout the projection period. The projections are determined by means of a mathematical formula, since they all represent lines which bear a specific relation to the X and Y axes in the Cartesian system of rectangular coordinates. The values of X are determined by the years and the values of Y are determined by the population sizes. In the formula, a is defined as the initial population and b as the rate of change. The formula may be written simply as: $Y = a + b X$.[6]

A second methodological problem must also be faced in computing population projections. This is the question of what base period to use in determining rate of population change. At best, it is a matter of debate as to what constitutes a "normal" period. It may be argued that we have not had a "normal" period in recent U. S. history, what with World War II, the Korean "Police Action," the "Cuban Crisis," etc. Despite these historical developments, the writers feel the decade 1950 to 1960 provides a relatively sound basis for making shorttime projections of the state's population.

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[3] William Peterson, *Population* (New York: The MacMillan Company, 1961) pp. 209-241.

[4] T. Lynn Smith, *Population Analysis* (New York: McGraw-Hill, 1948) p. 383.

[5] From 1958 until 1964 the U. S. Census used a "component" method to develop population projections. That is, separate projections were made for each component of change—births, deaths, and net migration—on the basis of certain assumptions. The most recent Census projections of the total U. S. population followed a new procedure. Computations were made using the "cohort" method of projecting fertility rates for birth cohorts of women (i.e. women born in the same year). A mortality allowance was based on projected life—table survival rates, and an assumption made that the future net immigration will amount to 300,000 annually and will be distributed by age and sex as in the period 1957 to 1962.

Obviously, this is a highly refined methodological approach. It involves access to resources of data, time, and money which are beyond the scope of the present study. However, it is of interest that the arithmetic method obtains approximately the same population estimate for the U. S. in 1964.

[6] For example: $a = 3,257,022$ (the population of Louisiana in 1960); $b = 57,351$ (the mean annual arithmetic change in population from 1950 to 1960); $X =$ Number of years since 1960; $Y =$ projected population.

A general justification for placing greater credence on projections based on the recent past is found in the words of two scholars, Hamilton and Perry, who have made an exhaustive study of population projections based on census data. These two scholars state that the big problem is that of deciding just what assumption to make and how many alternate projections to make.[7] Their feeling is that demographers have carried the making of several alternate projections based on corresponding assumptions too far and, thereby, confused consumers and users of projections. They say, "A simple point estimate of future population, with a word of warning and a short discussion of the possible errors involved is, we think, from the user's point of view, a better product of the demographers art."[8] In the same discussion, Hamilton and Perry suggest that if only one projection is to be provided, the most reasonable assumption to make is that vital rates of the recent past will continue unchanged into the near future. They defend this statement by noting that the events of the near future are organically and functionally tied to and dependent upon the events of the recent past.

The persons using the projections presented in this report are cautioned that they represent nothing more than the extension of past trends into the future. In this regard, it may be repeated that the projections of the population for the state as a whole will probably have greater reliability than that for the cities and parishes. The writers claim no more for the latter than the fact that they are an educated speculation on what is to come. The base data for this study have been taken from the various pertinent U. S. Census publications.

Louisiana Population Projections by Race and Residence

The projections of the state's population are presented in the following pages. Table 1 shows the projections of the state's population based on the assumption that the mean annual growth will be characteristic of the period 1950 to 1960.

It can be seen in Table 1 and Figure 1 that if recent growth trends hold, the people of the state will number 3,830,000 by 1970. This total will represent a 17.5 percent increase from 1960. The drop from 21.4 per-

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[7] C. Horace Hamilton and Josef Perry, "A Short Method for Projecting Population by Age From One Decennial Census to Another," *Social Forces*, XLI, December, 1962, p. 164.

[8] *Ibid.*

TABLE 1.–Louisiana Population Projections By Residence and Race to 1970, Based on the Mean Annual Arithmetic Change, From 1950 to 1960

	Population (in thousands)[1]				
		Residence		Color	
Year	Total	Urban	Rural	White	Nonwhite
1960	3,257	2,061	1,196	2,212	1,045
1961	3,314	2,120	1,194	2,254	1,061
1962	3,372	2,179	1,193	2,295	1,077
1963	3,429	2,237	1,191	2,337	1,092
1964	3,486	2,297	1,189	2,378	1,108
1965	3,544	2,356	1,188	2,420	1,124
1966	3,601	2,414	1,186	2,461	1,140
1967	3,658	2,473	1,185	2,503	1,156
1968	3,715	2,532	1,183	2,544	1,171
1969	3,773	2,591	1,181	2,586	1,187
1970	3,830	2,650	1,180	2,627	1,204

[1] Totals in this table were obtained by rounding computed totals and hence are not always equal to the sum of the rounded figures shown by residence and race.

cent increase experienced from 1950 to 1960 is explained in terms of using an arithmetic rather than a geometric rate of computing projections.[9]

Residence group projections show that the population of the state will be composed of 2,650,000 urban people and 1,180,000 rural people in 1970. This growth pattern will jump the percentage of urban people in the state to 69.3 percent, a percentage increase of 13.1 percentage points over 1960. The rural population will experience a proportional loss, dropping to 30.7 percent of the total state population.

Projections of the race groups indicate the relative position of the nonwhite and white populations will change little during the next decade. Approximately 2,627,000 or 68.7 percent of the state's people will be white in 1970 and 1,204,000 or 31.4 percent will be nonwhite. These percentages indicate a .7 percent drop in the percentage of nonwhites in the state.

It is clear the state is increasing its population at a fairly rapid rate. It is also obvious that the rural population will continue to decline. The steady shift toward an urban population will probably cause problems of housing, schooling, etc., in the towns and cities of the state. In contrast, the rural regions of the state will be faced with a gradually decreasing population. The ramifications of this trend in terms of support of social institutions, such as schools, churches, and businesses are clear. Another implication of the urbanization trend in population is a gradual change

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[9] It is gratifying to discover that the population estimates released by the U. S. Census on March 2, 1964 (Series P-25) place the July 1, 1962 Louisiana population at 3,371,000. This is just 1,000 persons less than the 1962 population projected for this publication. The small discrepancy can be accounted for in terms of the changes in armed forces personnel and date of the 1960 census enumeration plus the use of an average annual growth rate.

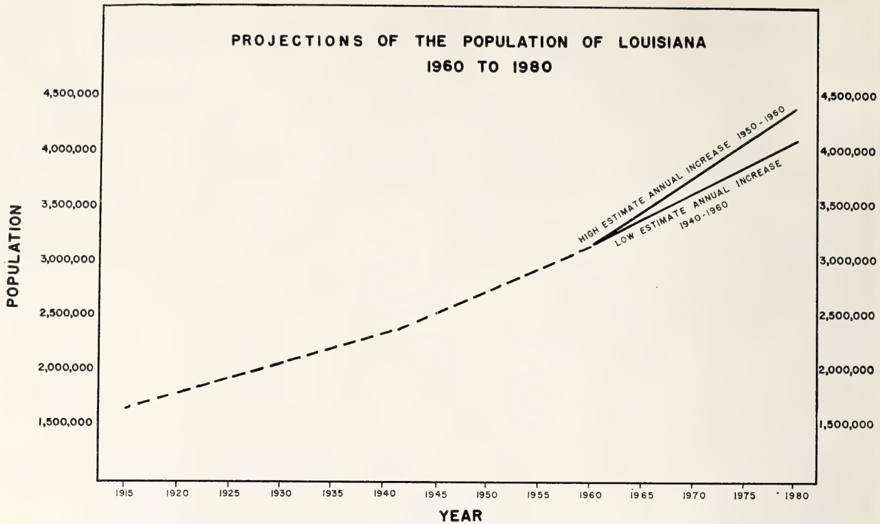

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FIGURE 1.

in the prevailing attitudes, values, and life orientations of the people of the state. The basic conservativeness traditional of rural Louisianians may give way to more liberal views characteristic of an urban middle class society.

Conceivably, planners at the state and local levels will have to approach urban planning problems in a more systematic fashion. It has already been suggested that a national system of many more small metropolitan centers systematically spaced to maximize community living and minimize congestion, air pollution, problems of water and sewerage, and social problems of crime and disorder might have important advantages over large urban concentrations.[10]

It is also significant that the state will continue to have one of the largest nonwhite populations of any state through the next decade, although the white population will assume a relatively stronger position. The urbanized movement of Negroes will have implications in terms of race relations, urban renewal, etc.

Population Projections for Louisiana's Major Cities

Urban places are gradually becoming more vital in the economic structure of the state. Our cities should thus be studied carefully and planned for wisely. Although the projections for such small population bases are risky and speculative at best, they can be used as checks to further trends.

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[10] Phillip M. Hauser (editor), *The Population Dilemma* (Inglewood Cliffs, New Jersey: Prentice Hall, Inc., 1963), p. 88.

TABLE 2.—Projections of the Population of the Standard Metropolitan Area of New Orleans by Race to 1970, Based on the Mean Arithmetic Change from 1950 to 1960[1]

Year	Total	White	Nonwhite
1960	868,480	599,200	269,280
1961	886,788	610,632	276,156
1962	905,096	622,064	283,032
1963	923,404	633,496	289,908
1964	941,712	644,928	296,784
1965	960,020	656,360	303,660
1966	978,328	667,792	310,536
1967	996,636	679,224	317,412
1968	1,014,944	690,656	324,880
1969	1,033,252	702,088	331,164
1970	1,051,560	713,520	338,040

[1] Totals in this table were obtained by rounding computed totals and hence are not always equal to the sum of the rounded figures shown by race.

TABLE 3.—Projections of the Population of the Standard Metropolitan Area of Shreveport by Race by 1970, Based on the Mean Arithmetic Change from 1950 to 1960[1]

Year	Total	White	Nonwhite
1960	281,481	185,479	96,002
1961	287,961	190,395	97,566
1962	294,441	195,311	99,130
1963	300,921	200,227	100,694
1964	307,401	205,143	102,258
1965	313,881	210,059	103,822
1966	320,361	214,975	105,386
1967	326,841	219,891	106,950
1968	333,321	224,807	108,514
1969	339,801	229,723	110,078
1970	346,276	234,639	111,637

[1] Totals in this table were obtained by rounding computed totals and hence are not always equal to the sum of the rounded figures shown by race.

TABLE 4.—Projections of the Population of the Standard Metropolitan Area of Baton Rouge by Race to 1970, Based on the Mean Arithmetic Change from 1950 to 1960[1]

Year	Total	White	Nonwhite
1960	230,058	156,895	73,163
1961	237,240	161,995	75,245
1962	244,422	167,095	77,327
1963	251,604	172,195	79,409
1964	258,786	177,295	81,491
1965	265,968	182,395	83,573
1966	273,150	187,495	85,655
1967	280,332	192,595	87,737
1968	287,514	197,695	89,819
1969	294,696	202,795	91,901
1970	301,878	207,895	93,983

[1] Totals in this table were obtained by rounding computed totals and hence are not always equal to the sum of the rounded figures shown by race.

TABLE 5.—Projections of the Population of the City of Lake Charles by Race to 1970, Based on the Mean Annual Arithmetic Change from 1950 to 1960[1]

Year	Total	White	Nonwhite
1960	63,392	49,635	13,757
1961	65,604	51,612	13,920
1962	67,816	53,589	14,227
1963	70,028	55,566	14,462
1964	72,240	57,543	14,697
1965	74,452	59,520	14,932
1966	76,664	61,497	15,167
1967	78,876	63,474	15,402
1968	81,088	65,451	15,637
1969	83,300	67,428	15,872
1970	85,512	69,405	16,107

[1] Totals in this table were obtained by rounding computed totals and hence are not always equal to the sum of the rounded figures shown by race.

TABLE 6.—Projections of the Population of the City of Monroe by Race to 1970, Based on the Mean Arithmetic Change from 1950 to 1960[1]

Year	Total	White	Nonwhite
1960	52,219	29,370	22,849
1961	53,583	30,119	23,464
1962	54,947	30,868	24,079
1963	56,311	31,617	24,694
1964	57,675	32,366	25,309
1965	59,039	33,115	25,924
1966	60,403	33,864	26,539
1967	61,767	34,613	27,154
1968	63,131	35,362	27,769
1969	64,495	36,111	28,384
1970	65,859	36,860	28,999

[1] Totals in this table were obtained by rounding computed totals and hence are not always equal to the sum of the rounded figures shown by race.

Projections for the population of New Orleans, Baton Rouge, Shreveport, Lake Charles, Monroe, Lafayette, and Alexandria are presented in this section. They are presented in rank order of size as determined by the 1960 Census.

One important factor should be noted in this regard. The Bureau of Census publishes data for what is termed the Standard Metropolitan Statistical Areas (SMSAs) of certain cities. (Except in New England, an SMSA is a county or group of contiguous counties that contains at least one city or cities. Nearby counties are included in an SMSA if they are classed as essentially metropolitan in character and are socially and economically integrated with the central city.)[11] Baton Rouge, Shreveport,

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[11] See, U. S. Bureau of Census, *U. S. Census of Population: 1960. General Population Characteristics, Louisiana,* Final Report, EC (1) — 20B, U. S. Government Printing Office, Washington, D. C., 1961, p. VIII.

TABLE 7.—Projections of the Population of the City of Lafayette by Race to 1970, Based on the Mean Arithmetic Change from 1950 to 1960[1]

Year	Total	White	Nonwhite
City of Lafayette before annexation[2]			
1960	40,400	28,973	11,427
1961	41,086	29,348	11,738
1962	41,772	29,723	12,049
City of Lafayette after annexation[2]			
1963	50,312	35,721	14,590
1964	51,152	36,318	14,833
1965	51,992	36,915	15,076
1966	51,832	37,514	15,316
1967	53,672	38,108	15,563
1968	54,512	38,705	15,806
1969	55,352	39,302	16,049
1970	56,192	39,899	16,292

[1] Totals in this table were obtained by rounding computed totals and hence are not always equal to the sum of the rounded figures shown by race.

[2] Additional territory, including approximately 9,700 persons in 1963 was annexed to the city after 1960 census.

TABLE 8.—Projections of the Population of the City of Alexandria by Race to 1970, Based on the Mean Annual Arithmetic Change from 1950 to 1960[1]

Year	Total	White	Nonwhite
1960	40,279	22,779	17,500
1961	40,816	23,014	17,802
1962	41,353	23,249	18,104
1963	41,890	23,484	18,406
1964	42,427	23,719	18,708
1965	42,964	23,954	19,010
1966	43,501	24,189	19,312
1967	44,038	24,424	19,614
1968	44,575	24,659	19,916
1969	45,112	24,894	20,218
1970	45,649	25,129	20,520

[1] Totals in this table were obtained by rounding computed totals and hence are not always equal to the sum of the rounded figures shown by race.

and New Orleans are the only cities in Louisiana for which data are collected on a metropolitan area basis. The Baton Rouge Standard Metropolitan Statistical Area comprises East Baton Rouge Parish. The New Orleans Standard Metropolitan Statistical Area includes Jefferson, Orleans, and St. Bernard parishes, and the Shreveport Standard Metropolitan Statistical Area is composed of Caddo and Bossier parishes. For these cities, projections were based on the SMSA population. The actual population (within city limits) of the remaining cities was used for the projections, since neither one has a legally defined metropolitan area.

New Orleans

Table 2 gives population projections for the Standard Metropolitan Statistical Area of New Orleans. According to these calculations, the SMSA of New Orleans will have 1,051,560 persons in 1970. Approximately two thirds (68.7 percent or 713,000) of the people of this city will be white. Some 32.2 percent or 338,040 will be nonwhite. It can be seen that the New Orleans SMSA will pass the one million mark, which is considered a landmark for cities.

Shreveport

Table 3 includes population projections for the SMSA of Shreveport. The projections include a population of approximately 346,276 in 1970. This population will include 234,639 white (67.6 percent) and 111,737 nonwhites (32.4 percent).

Baton Rouge

Table 4 presents projections for the SMSA of Baton Rouge. These estimates reveal that the population of this metropolitan area will be 301,878 in 1970. Here again, the percentage white is well over two-thirds, 68.5 percent, including 207,895 persons. Nonwhites will represent 31.5 percent of the population, including 93,833 persons.

Lake Charles

The population projections for the city of Lake Charles are presented in Table 5. These projections indicate that this city will have 85,512 persons in 1970. Of this number, 69,405 (82 percent) will be white and 16,107 will be nonwhite, a mere 18 percent of the total population of the city. Lake Charles will have the smallest nonwhite population of any major city in the state.

Monroe

The population projections for Monroe are presented in Table 6. If these projections hold, Monroe will have 65,859 persons in 1970. Of this number, 36,860 persons (55 percent) will be white. Some 28,999 persons (45 percent of the population) will be nonwhite.

Lafayette

Projections for the population of the city of Lafayette are presented in Table 7.

In this city, a special census was conducted in 1963, so as to include the area annexed since 1960. The area annexed included approximately 9,700 individuals in 1963, according to Census data.[12]

Projections based on the assumption of growth between 1950 and 1960 show the population of Lafayette will be 56,192 persons in 1970. Well over two-thirds of the city's population will be white. Only 29 percent will be nonwhite.

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[12] Series P-28, No. 1362, February 28, 1964.

Alexandria

Table 8 shows the projections of the population of Alexandria and indicates the 1970 population of the city will be 45,649. The number of whites, 25,129, is less than 5,000 more than the number of nonwhites, 20,252. Fifty-five percent of the population will be white. Alexandria is the only major city in Louisiana in which the nonwhite population will increase at a greater rate than the white population if current trends hold.

Implications of Urban Trends

All the major cities of Louisiana will show an increase in population in the next decade, if current trends of growth continue. In fact, the increase of these cities will represent the greater part of the state's population increase during this time. The rate of increase will, of course, vary from one city or metropolitan area to another. Lake Charles is expected to show the greatest percentage increase, 39 percent; followed by Baton Rouge, 31 percent; Shreveport and Monroe, 23 percent; New Orleans, 21 percent; and Lafayette, 16 percent. Any number of factors may change these projections, but nothing drastic appears to be on the horizon currently, except the Michoud Plant installation in the New Orleans area.[13] This is an operation of the Federal Government, which will be concerned on a large scale with defense efforts.

The population density of New Orleans proper has now reached 3,153.4 persons per square mile. Consequently, the population of the city cannot be expected to increase greatly but the nearby parishes can be expected to grow at a fast rate.

The New Orleans Standard Metropolitan Statistical Area will continue to include one of the largest nonwhite populations of any city in the United States. Monroe and Alexandria will continue to have larger percentages of nonwhites in their populations than the other major cities. Lake Charles will have the smallest nonwhite population.

The trends indicated are in keeping with the urban industrial revolution which has been going on in the state and nation for the past few decades. Along with obvious benefits, this revolution has brought and no doubt will continue to bring serious problems. The financing of schools, government, and welfare programs appears to be the greatest challenge which the people of these cities will have to face.

Population Projections for the Parishes of Louisiana

Many requests are received for projections of parish populations. For this reason, computations were made for each individual parish, despite some reluctance to publish data based on small populations. The small-

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[13] Should the optimistic reports of the newly-elected state officials materialize, the population of the state will be affected by increasing industrialization.

TABLE 9.—Projections of the Population of the Parishes of Louisiana to 1970, Based on the Mean Arithmetic Change from 1950 to 1960

	1970 Projected Population					
Parish	Total Population		White Population		Nonwhite Population	
	Number	Percent Increase/ Decrease 1960-70	Number	Percent Increase/ Decrease 1960-70	Number	Percent Increase/ Decrease 1960-70
Acadia	52,812	6.1	42,155	5.3	10,657	9.2
Allen	20,899	5.5	15,586	4.5	5,313	8.3
Ascension	33,467	24.7	23,558	31.4	9,909	12.5
Assumption	18,704	4.1	11,095	5.1	7,605	2.6
Avoyelles	37,181	—1.1	26,170	—3.4	11,011	5.4
Beauregard	20,616	8.0	15,033	0.9	5,583	42.2
Bienville	14,347	—12.5	7,244	—1.2	7,103	—12.2
Bossier	75,105	43.6	60,324	64.9	14,781	3.1
Caddo	271,171	26.8	174,315	29.0	96,856	22.8
Calcasieu	201,315	62.3	161,148	66.6	40,167	47.5
Caldwell	7,715	—12.5	5,641	—11.6	2,074	—14.6
Cameron	7,574	10.7	7,279	14.2	295	—24.6
Catahoula	11,008	—3.5	7,124	—3.6	3,884	—3.1
Claiborne	13,751	—22.6	7,186	—20.3	6,565	—24.6
Concordia	26,536	42.2	16,119	87.3	10,417	11.0
De Soto	24,098	—0.6	10,116	—2.7	14,092	0.9
East Baton Rouge	301,880	45.4	207,895	47.0	93,985	39.7
East Carroll	12,504	—11.5	4,869	—11.5	7,695	—11.3
East Feliciana	21,263	5.6	10,574	16.1	10,689	—2.0
Evangeline	31,649	5.6	22,243	—3.8	9,406	12.2
Franklin	22,800	—11.2	12,393	—16.6	10,407	—1.7
Grant	12,397	—6.5	9,406	—6.4	2,991	—6.7
Iberia	63,255	29.0	46,000	36.0	16,655	14.0
Iberville	33,128	11.9	16,882	11.7	16,246	12.0
Jackson	16,222	2.6	10,551	—1.3	5,671	11.7
Jefferson	313,665	101.0	266,086	101.1	47,579	96.2
Jefferson Davis	33,352	13.4	26,373	13.4	6,979	11.3
Lafayette	111,569	46.6	86,635	53.1	24,934	29.2
Lafourche	68,553	31.2	60,707	30.2	7,846	19.0
LaSalle	13,305	2.3	11,418	.5	1,887	16.2
Lincoln	31,288	10.7	17,772	7.6	13,516	15.1
Livingston	33,894	34.5	28,744	34.0	5,150	37.1
Madison	15,437	—5.8	5,643	—2.1	9,794	7.6
Morehouse	35,380	5.2	19,223	7.9	16,157	2.3
Natchitoches	33,162	—6.5	19,130	—4.5	14,032	—8.9
Orleans	684,605	10.0	397,374	1.2	287,231	28.6
Ouachita	128,613	36.1	87,765	37.7	40,848	32.7
Plaquemines	30,851	58.3	23,351	83.7	7,500	18.0
Pointe Coupee	23,135	3.0	10,754	3.1	12,381	2.7
Rapides	132,054	22.8	94,138	27.7	37,916	12.9
Red River	7,843	—17.6	4,407	—13.6	3,436	—13.6
Richland	20,976	—10.7	10,770	—15.7	10,206	—3.3
Sabine	16,248	—11.1	11,781	—14.4	4,467	1.9

(Continued)

TABLE 9.—(continued)

	1970 Projected Population					
Parish	Total Population		White Population		Nonwhite Population	
	Number	Percent Increase/ Decrease 1960-70	Number	Percent Increase/ Decrease 1960-70	Number	Percent Increase/ Decrease 1960-70
St. Bernard	53,285	190.3	50,058	214.4	3,227	49.4
St. Charles	29,075	58.8	21,946	71.8	7,129	31.7
St. Helena	9,311	1.7	3,924	—3.5	5,387	6.2
St. James	21,404	19.8	11,004	22.1	10,400	17.4
St. John the Baptist	22,017	24.1	10,407	14.8	11,610	28.2
St. Landry	84,510	3.8	49,428	6.8	35,082	.09
St. Martin	31,773	10.3	19,874	9.8	11,899	11.0
St. Mary	61,818	36.2	45,408	52.7	16,410	9.6
St. Tammany	50,298	43.2	37,002	47.0	13,296	33.8
Tangipahoa	65,650	11.7	42,011	7.3	23,639	21.2
Tensas	10,383	—10.7	3,612	—11.1	6,771	—10.4
Terrebonne	78,214	40.3	63,998	47.9	14,216	16.6
Union	16,107	—7.9	9,761	—11.0	6,346	—2.0
Vermilion	40,781	5.2	35,445	4.9	5,336	6.7
Vernon	17,628	—3.5	14,960	—5.3	2,668	10.1
Washington	49,659	14.7	31,911	10.6	17,748	23.5
Webster	43,698	11.2	29,330	14.6	14,368	5.1
W. Baton Rouge	17,854	26.1	9,507	36.4	8,347	16.8
West Carroll	11,106	—17.8	7,869	—22.1	3,237	1.8
West Feliciana	14,621	21.9	5,465	43.2	9.156	1.3
Winn	15,949	—0.5	10,360	—5.7	5,589	1.3
TOTAL	3,830,528		2,626,747		1,203,781	

er the population of the parish, the less statistical reliability the projections shown will have. Therefore, one should use the data given with a great deal of caution. It is quite certain, as mentioned earlier, that the Michoud Plant operation will affect the population of at least a dozen parishes in the southeastern part of the state, including Orleans, St. Tammany, Washington, St. James, St. Charles, St. Bernard, and possibly Jefferson and Tangipahoa. No attempt was made to allow for this or like developments in this report, because there is no reliable way to measure the changes which may come about. The reader should make his own corrections in the projections in the light of his personal knowledge of the situation in a given parish.

Nearly 30 percent of the parishes in Louisiana have been losing population for 20 years. All parishes which lost population between 1940 and 1950 also lost people between 1950 and 1960. Parishes which gained in one decade tended to show gains during the entire period studied. In the light of the above, it can be expected that both "losing" and "gaining" parishes will tend to level out or even reverse their trends at some point in the future. Projections, by their very nature, cannot show change except in one direction. The local observer may be aware of factors not apparent to the writer which would reverse recent trends.

Those parishes which lost population in the decade 1940 to 1950 and gained population between 1950 and 1960 tended to be in the southern part of the state. No parish south of Rapides Parish lost people in the latter decade while all parishes in the northern part of the state not including a city or near a major city suffered decreases in population. Apparently, proximity to a metropolitan area is an important factor in rate of growth. The 19 parishes which lost population from 1950 to 1960 declined from a total population of 438,785 in 1950 to a total population of 344,658 in 1960.[14] The projections made indicate this group of parishes will experience a further decline to 320,700 persons by 1970. On the other hand, the largest parishes of the state, those with a population above 100,000 in 1950, had nearly 56 percent more inhabitants in 1960 than in 1940.[15] On the basis of the projections computed, these parishes will increase 19.4 percent during the decade 1960-1970. This rate will result in an increase of population from 1,439,931 in 1960 to 1,791,638 in 1970. These six parishes included 39 percent of the population of the state in 1940 and 44.2 percent of the state's people in 1960. By 1970 these six parishes will have 44.6 percent of the total population of the state, according to the computations made. The projections to 1970 for each of the parishes is shown in Table 9.

Approximately one-third (32.1 percent) of the state's population was classified as nonwhite in 1960. This percentage represented a drop of one percentage point from 1950. Nonwhites remained heavily concentrated in the Mississippi and Red River Delta areas of Louisiana. Parishes with a small nonwhite population were found along the Gulf Coast. The projections indicate that the following parishes will have more than one-third increase of nonwhites from 1960 to 1970: Beauregard, 42.2 percent more nonwhites; Calcasieu, 47.5 percent; East Baton Rouge, 39.7 percent more nonwhites; St. Bernard, 49.4 percent; Jefferson, 96.2 percent; and Livingston, 37.1 percent more nonwhites. The following parishes will experience at least 10 percent loss in their nonwhite population: Claiborne, 24.6 percent; Red River, 13.6 percent; and East Carroll, 11.3 percent. Orleans Parish will continue to have the largest absolute number of nonwhites, with a projected total of 287,231. This number represents an increase of 28.6 percent over its 1960 nonwhite population. The parish with the smallest nonwhite population in 1970 will be Cameron with only 295 nonwhite residents, representing just 3 percent of the total inhabitants of the parish.

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[14] Claiborne, West Carroll, Red River, Bienville, Caldwell, Beauregard, Catahoula, DeSoto, East Carroll, Franklin, Grant, Madison, Natchitoches, Richland, Sabine, Tensas, Union, Vernon, Winn.

[15] Caddo, East Baton Rouge, Jefferson, Orleans.

Implications of Parish Population Trends

The parish, in Louisiana, is an important social, economic, and political unit. In general, a look to the future indicates that the parishes which will continue to lose population are rural, while those which show promise of continued growth are urban. Parishes near the large metropolitan centers can be expected to gain at the fastest rate. The projections also indicate that, in general, the parishes in the southern part of the state will continue to outgrow parishes in the northern part of the state. These trends have serious implications for both local and state officials as well as for private citizens. The matters of adequate schools, roads, welfare programs, and support of religious, government, and economic institutions loom large. However, it may be even more important that urbanization trends in the state show significant changes in the value orientation of the state's people, including shifts in education and political philosophy and in basic ideology.

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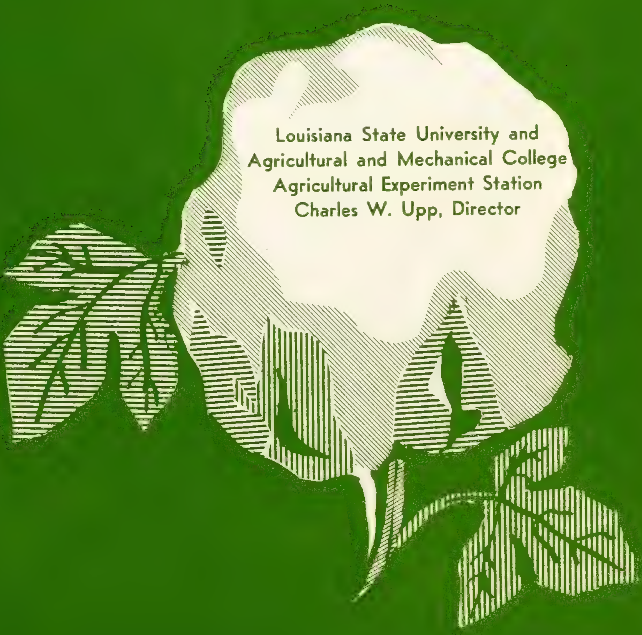
Effects of Planting Date, Time of Fruiting And Use of Insecticides On Yield and Fiber Quality of Cotton

Lucille Finley, A. D. Oliver and L. W. Sloane



Louisiana State University and
Agricultural and Mechanical College
Agricultural Experiment Station
Charles W. Upp, Director

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Effects of Planting Date, Time of Fruiting, and Use of Insecticides on Yield and Fiber Quality of Cotton

LUCILLE FINLEY,[1] A. D. OLIVER,[2] AND L. W. SLOANE[3]

INTRODUCTION

The effect of insect infestations on cotton yields is well known. Information is limited relative to the effect of insect infestations, the use of insecticides, date of planting, or time of fruiting on the quality of cotton fiber. During the last decade early application of insecticides to control cotton insects has been increasingly recommended in some areas.

Increased emphasis on higher quality fiber by cotton goods manufacturers reflects the importance of any practice that may influence fiber quality. Fiber length, strength, and fineness are physical properties in current use to determine quality of raw cotton fiber. Studies reported in this bulletin were made to determine if date of planting, time of fruit setting as determined by defloration, and various insect control practices affect fiber quality.

METHODS AND MATERIALS

Cotton used in these studies was produced on the Northeast Louisiana Agricultural Experiment Station at St. Joseph and Winnsboro, Louisiana, from 1956 to 1960. Land preparation, fertilization, and cultivation practices were according to recommendations of the Louisiana Agricultural Experiment Station. Treatments in all experiments were replicated four times in randomized block designs.

Fiber analyses were made in the textile research laboratory at Louisiana State University under controlled conditions of humidity and temperature. All testing was done after samples had been conditioned in the testing laboratory for at least 24 hours. Fiber length was measured on the fibrograph. The upper half mean length, as determined by the fibrograph, provided a measure of the average length expressed in terms of decimal fractions of an inch. Fiber fineness was measured by the micronaire. Micronaire readings indicate the resistance of passage of air through a 50-grain sample in a fixed chamber. Fiber strength tests were made with a $\frac{1}{8}$-inch spacer between Pressley jaws ($\frac{1}{8}$-inch gauge) fitted to a Stelometer, a pendulum type fiber strength tester. Three factors

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[1] Assistant Professor, Home Economics.

[2] Associate Professor, Entomology.

[3] Assistant Professor, Agronomy, Northeast Louisiana Experiment Station.

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of cotton quality, fiber strength (⅛-inch gauge), upper half mean length in inches, and fiber weight per inch (micronaire) in micrograms, were used to calculate strength of 22's yarn according to Webb's (1956) formula.[4]

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Date of Planting

Fiber used in this experiment was from field experiments conducted at St. Joseph, Louisiana, in 1959 and 1960. The cotton varieties Stoneville 3202 and Stardel were planted on April 15, May 1-2, and May 15. Insects were effectively controlled by applying 0.25 and 0.50 pound of Guthion-DDT per acre on a 4 to 5-day interval until maturity. The cotton was hand-picked in three pickings for each year. In 1959 the cotton was picked on September 17, October 21, and November 13. In 1960 the pickings were made between the dates of October 2 and 13. Cotton from the three pickings of each treatment was combined, blended, and ginned on a roller-type gin. After ginning, the fiber was blended and a composite sample withdrawn for laboratory analyses.

Defloration Experiment

Fiber used to determine the effect of time of fruit set was obtained from defloration experiments conducted in 1956 and in 1958 to 1960. Fruit set was controlled by removing by hand all squares (flower buds) match head size and larger from the plants at weekly intervals. Individual plots consisted of three rows 25 feet long. Cotton varieties grown were Coker 100 WR in 1956; Stardel in 1958; Deltapine 15 and Stoneville 3202 in 1959; and Stardel in 1960. Fiber obtained from treatments in which the fruit was removed for 0, 3, and 7 weeks, respectively, after the cotton began to fruit was used as a representative of fiber from early season, midseason, and late season fruiting. In 1959 the cotton was harvested in three pickings from the early and midseason fruiting plots. Plots in the late fruiting treatment were harvested in two pickings. In 1960 all squares match head size and larger were removed by hand at weekly intervals for 0, 1, 2, 3, 4, 5, 6, and 7 weeks, respectively. Insects in all plots were effectively controlled with toxaphene, DDT, methyl parathion, and Guthion from time of plant emergence until all bolls were matured beyond the stage susceptible to insect attack.

Insecticide Experiment

In 1959 and 1960 a study was made to determine the effect of several insecticides and schedules of application on fiber quality. The variety Stoneville 3202 was planted in 1959 and Stardel in 1960. Individual plots consisted of 12 rows 150 feet long. Cultural practices were identical in all plots. The insecticide treatments were: (1) Check (no insect control); (2) nineteen applications of toxaphene-DDT (2 pounds + 1 pound per acre) for complete control of cotton insects throughout the growing season; (3) nine applications of toxaphene-DDT (2 pounds + 1 pound per acre) beginning when boll weevil infestation reached 25 percent punctured squares; (4) nine applications of Guthion-DDT (0.25 pound + 0.50 pound per acre) for cotton insect control after boll weevil infestation reached 25 percent punctured squares. There were moderate to heavy infestations of thrips, *Franklinella fusca* (Hinds); tarnished plant bugs, *Lygus lineolaris* (Palisot de Beauvois); cotton fleahoppers, *Psallus seriatus* (Reuter); and boll weevils, *Anthonomus grandis* Boheman, in all plots until control was initiated. These insects were effectively controlled with the insecticides. Insecticide application was discontinued concurrently in all treatments. Cotton from plots treated with the various insecticides on different schedules of application was harvested in two pickings.

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[4] Webb, Robert W. *Equations for Predicting Cotton Processing Performance and Product Quality by Improved Evaluations of Raw Cotton Quality*. U.S.D.A., AMS, Marketing Research Report No. 114, 16, 1956.

In 1960 the following treatments were compared for effects on quality of fiber: (1) Eight applications of methyl parathion-DDT (0.25 + 0.50 pound per acre) beginning at first squaring; (2) eight applications of toxaphene-DDT (2.0 pounds + 1.0 pound per acre) beginning at squaring but preceded by two applications of toxaphene (2.0 pounds per acre) for thrips control; (3) eight applications of toxaphene-DDT (2.0 pounds + 1.0 pound per acre) beginning at first squaring; (4) eight applications of Sevin (1.0 pound per acre) beginning at first squaring; (5) eight applications of methyl parathion-endrin (0.25 pound + 0.50 pound per acre) beginning at first squaring; (6) check (no control). These treatments ended August 6. All plots, including the check, received eight additional applications of the methyl parathion-DDT mixture during August and September for boll weevil and bollworm control. Cotton from the three pickings of each treatment was combined, blended, and ginned on a roller-type gin. It was again blended after ginning and a 10-gram sample removed from the composite sample for fiber testing.

Data for all experiments were subjected to analysis of variance to determine if significant differences existed among treatments.

RESULTS AND DISCUSSION

Data from the experiments conducted from 1956 to 1960 do not support claims that better quality cotton fiber is produced by the early fruiting of cotton which is influenced by early planting and early season insect control.

Date of Planting

The date of planting cotton materially influenced fiber qualities. Cotton planted on May 15 produced high levels of fiber quality. In 1959 there was no significant difference in yield of seed cotton among the three dates of planting. In 1960, cotton planted on May 15-16 yielded significantly more seed cotton than that planted on April 15-16 or

TABLE 1.—Yield and Fiber Properties of Cotton for Three Dates of Planting, St. Joseph, Louisiana

	Dates of Planting 1959 (Stoneville 3202)			Dates of Planting 1960 (Stardel)		
Attribute	4/15	5/1-2	5/15	4/15-16	5/1-2	5/15-16
Yield SC/A (lbs.)	2,127	2,440	2,293	1,694	2,244*	2,777**
Fiber Length, U.H.M. (inches)	1.02	1.04	1.05	1.00	1.04	1.09
Fiber Strength (grams/tex, 1/8 gauge)	13.30	13.40	14.60	17.50	18.40	18.10
Fiber Fineness (micronaire units)	4.68	4.48	4.13	4.80	5.20	4.90
Fiber Elongation (percent)	7.80	8.20	9.40**	6.20	7.00	6.60*
Non-Lint Content (percent)	...	...	...	6.43	5.26	4.15*

* Significant at .05% level.
**Significant at .01% level.

May 1-2. Cotton planted on May 1-2 yielded significantly more seed cotton than that planted April 15-16. These data are shown in Table 1 and Figure 1. Differences in fineness, strength, and elongation between Stoneville 3202 and Stardel for each planting date would be accounted for in the highly significant difference between years in which each variety was planted. Fiber length and strength increased for Stoneville 3202 and Stardel planted May 15. Non-lint content was significantly lower and fiber elongation significantly higher for the cotton planted May 15.

The calculated yarn strength increased for fiber from the later planting dates in each year. Stoneville 3202 fiber showed an increase of 2.09 pounds between cotton planted on April 15 and May 1; an increase of 2.54 pounds between May 1 and May 15 plantings, and a total increase of 4.63 pounds between cotton planted April 15 and May 15. Stardel cotton planted in 1960 showed an increase of 0.55 pound in strength between cotton planted April 15-16 and May 1-2; an increase of 4.01 pounds between cotton planted on May 1-2 and May 15-16, and an increase of 4.56 pounds between cotton planted April 15-16 and May 15-16.

Defloration

Yields and fiber quality of cotton as influenced by defloration are shown in Tables 2 and 3. There were no differences in fiber quality of the cotton produced in the early and midseason plots of the deflorated experiments in 1956, 1958, and 1959. Coker 100 WR exhibited no differences in fiber quality except elongation regardless of the number of weeks the fruit was removed in 1956. Fiber qualities of length and fineness were lower in Stardel cotton produced in 1958 by plants that were deflorated for 7 weeks after fruiting began. The differences in length and fineness were significant at 7 weeks.

There was no significant difference in yield of seed cotton from plants deflorated for 0, 3, and 7 weeks after fruiting began at St. Joseph in 1956.

In 1958, plants deflorated for 3 weeks produced significantly more

FIGURE 1.—Effect of Planting Dates on Fiber Properties of Stardel and Stoneville 3202 Cotton, 1959-1960, St. Joseph, La.

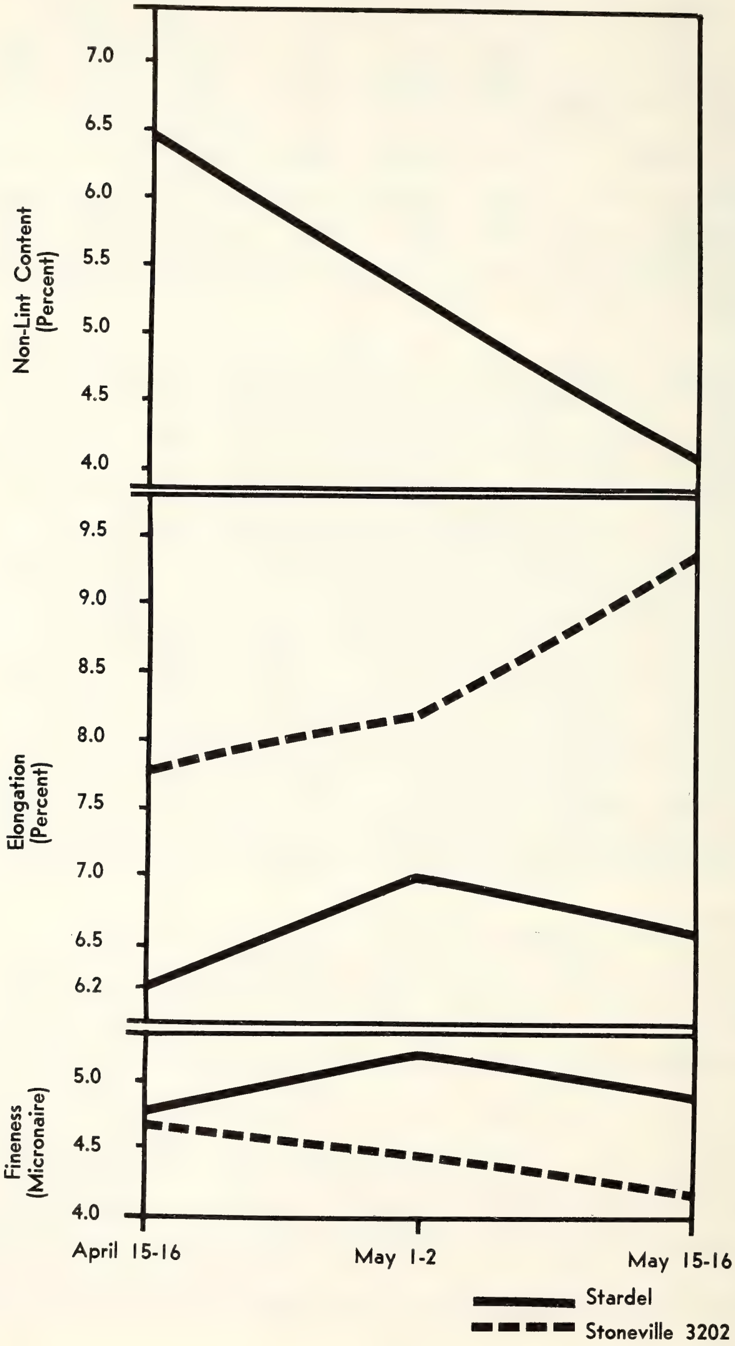

FIGURE 1 (Continued)

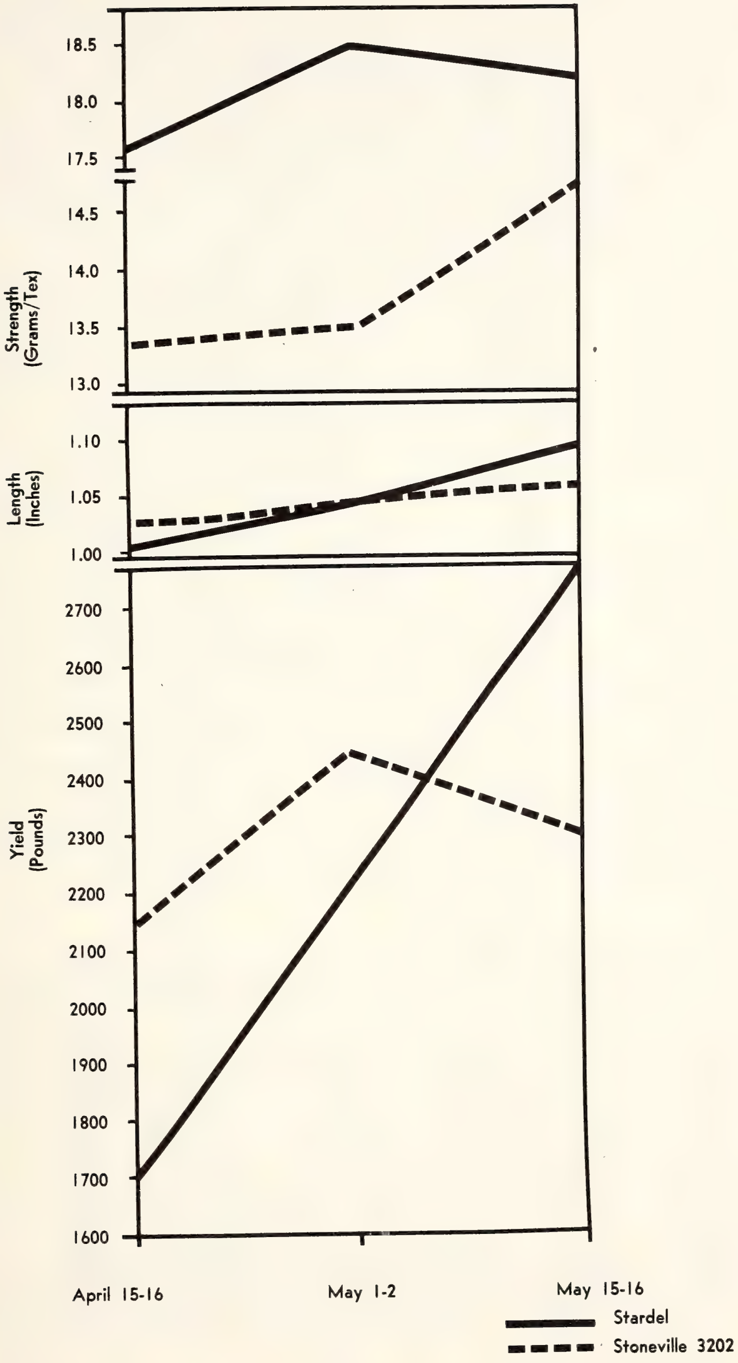

TABLE 2.—Comparison of Cotton Yield and Fiber Properties of Cotton Allowed to Set Fruit After Defloration for 0, 3, and 7 Consecutive Weeks

	Number of Weekly Fruit Removals											
	1956 (Coker 100 WR)[a]			1958 (Stardel)[a]			1959 (Stoneville 3202)[a]			1959 (DPL 15)[b]		
Attributes	0	3	7	0	3	7	0	3	7	0	3	7
Yield in Seed Cotton/A (lbs.)	2,827	3,065	3,186	2,128	2,623*	1,987	2,847**	2,796**	1,837	2,319**	2,211**	1,362
Fiber Length, U.H.M. (inches)	1.10	1.08	1.11	1.14	1.16	1.10**	1.05	1.06	1.02	1.05	1.04	1.06
Fiber Strength (grams/tex, ⅛ gauge)	16.50	19.30	18.60	18.40	18.20	18.10	14.70	14.30	16.20**	17.30	17.00	17.60
Fiber Fineness (micronaire units)	4.39	4.22	4.40	3.78	3.70	3.18*	4.30	4.16	3.56*	4.78	5.26	3.10**
Fiber Elongation (percent)	7.20	7.60	8.50**	7.60	8.10	7.80	9.30	9.70	9.40	7.80	7.70	10.10**

[a] St. Joseph Station.

[b] Winnsboro Station.

* Significant at .05% level.

**Significant at .01% level.

seed cotton than plants that were allowed to set fruit normally or were deflorated for 7 weeks after fruiting began. There was no difference in yield between 0 defloration (no fruit removed) and defloration for 7 weeks after fruiting began.

In 1959, cotton deflorated at St. Joseph and Winnsboro for 0 and 3 weeks after fruiting began yielded significantly more seed cotton than those plants that were deflorated for 7 consecutive weeks after fruiting began. There was no significant difference in yield of seed cotton from plants deflorated for 0 and 3 weeks after fruiting began. In 1959, Stoneville 3202 produced fiber of less length and fineness when deflorated 7 weeks at St. Joseph. The increase in fiber strength of Stoneville 3202 in 1959 was highly significant and seemed to be associated with finer fiber. Other varieties did not react in this manner.

The yield of Deltapine 15 seed cotton was greater for the 0 and 3-week treatments at Winnsboro. The difference in finer fiber was highly significant for 7 weeks of defloration. Fiber elongation increased by a significant amount with 7 weeks of defloration. There were no differences in quality of fiber in any variety in any year at either location when deflorations were made up to 3 weeks after fruiting began, compared to fruit allowed to develop normally.

In 1960, the time of fruit set resulted in significant differences in yield and, at certain intervals of treatments, in fiber strength, fineness, and elongation of cotton grown at St. Joseph, as shown in Table 3. All cotton deflorated for 1 to 7 weeks produced significantly more seed cotton than plants not deflorated at all. Plots deflorated until July 11, or up to 5 weeks after fruiting began, showed a significant linear increase in yield over those deflorated a fewer number of times. A significant decrease in yield occurred for plots defruited more than 5 weeks. Fiber length and strength increased through 5 weeks of defloration, then showed a slight decrease at 6 and 7 weeks of defloration. The difference among means for length and strength was highly significant for both linear and quadratic response. The F test showed no difference among

TABLE 3.—Comparison of Fiber Properties of Stardel Cotton Allowed to Set Fruit After Defloration for 0 Through 7 Weeks, 1960, St. Joseph, Louisiana

Weeks Fruit Removed (Deflorated)	Length, U.H.M. (inches)	Strength (grams/tex, ⅛ gauge)	Fineness (micronaire units)	Elongation (percent)	Non-lint Content (percent)	Yield SC/A (lbs.)
0	1.07	16.80	5.00	6.20	3.51	1,783
1	1.08	16.80	4.90	6.40	4.12	2,386*
2	1.08	17.00	4.78	6.60	3.82	2,770*
3	1.11	17.60	4.65	6.70	3.84	2,852*
4	1.12	18.30*	4.78	6.80	3.51	3,056*
5	1.12	18.40*	4.75	7.10	3.68	3,027*
6	1.09	17.60	4.75	7.10	3.54	2,632*
7	1.11	17.70	4.55*	7.20	3.78	2,691*

*Significant at .05% level.

means for fiber length, but the difference in fiber strength was significant for 4 and 5 weeks of defloration. Difference among means for fineness was highly significant in linear and quadratic response, with mean fineness at 7 weeks lower by a significant amount. Increase in fiber elongation showed a linear response through 7 weeks of defloration. The difference among means for non-lint content was not significant as measured by the F test and linear and quadratic response. Non-lint content was not affected by treatment. Over-all quality of fiber was higher from plants that were not allowed to set fruit for a period of 3 to 5 weeks after fruiting began.

Insecticide Tests

Results obtained from the insecticide experiments conducted in 1959-1960 are shown in Tables 4 and 5. In 1959 and 1960, there were no significant differences in yield among treatments which received applications of insecticides on the various schedules for insect control. All treatments yielded significantly more cotton than the plots receiving no protection.

TABLE 4.—Effect of Several Insecticides and Schedules of Application on Fiber Quality and on Yield of Stoneville 3202 Cotton, St. Joseph, Louisiana, 1959

Treatment	Dosage (lbs./acre)	Length, U.H.M. (inches)	Strength (grams/tex, ⅛ gauge)	Fineness (micronaire units)	Elongation (percent)	Yield SC/A (lbs.)
Untreated Check	0	1.05	14.0	4.45*	8.60	1,685
Toxaphene-DDT, 19 applications	2-1	1.05	14.0	4.28	8.20	2,432*
Toxaphene-DDT, 9 applications	2-1	1.06	14.0	4.33	8.40	2,191*
Guthion-DDT, 9 applications	0.25-0.5	1.06	14.6	4.37	8.60	2,322*

*Significant at .05% level.

TABLE 5.—Effect of Several Insecticides and Schedules of Application on Fiber Quality of Stardel Cotton, St. Joseph, Louisiana, 1960

Treatment	Length, U.H.M. (inches)	Strength (grams/tex, ⅛ gauge)	Fineness (micronaire units)	Elongation (percent)	Non-lint Content (percent)	Yield SC/A (lbs.)
Untreated Check	1.05	17.71	4.78	6.78	6.50	1,742
Methyl Parathion-DDT	1.06	17.48	4.75	6.55	6.49	2,047*
Toxaphene-DDT plus Toxaphene	1.01	17.48	4.68	6.48	7.72	2,026*
Toxaphene-DDT	1.03	17.52	4.75	6.42	5.09	1,960
Sprayable Sevin	1.02	17.12	4.82	6.25	6.94	2,069*
Methyl Parathion-Endrin	1.06	17.16	4.68	6.68	6.94	2,102*

*Significant at .05% level.

In 1959, finer fiber was obtained from **cotton** produced on plots treated with insecticides, regardless of application schedule. The level in quality of fiber length, strength, and elongation did not show any difference between cotton produced on treated and untreated plots. Plants treated with 19 applications of toxaphene-DDT to give protection from thrips, fleahoppers, lygus bugs, bollworms, and boll weevils produced cotton fiber of the same quality as plants that received 9 applications of toxaphene-DDT or Guthion-DDT, beginning when boll weevil infestation reached 25 percent, to control boll weevils and bollworms.

Results of the experiment conducted in 1960 showed that fiber produced by plants protected early in the growing season did not differ in quality from fiber produced by plants that received the first application of insecticide at later dates. Quality of fiber was not affected by the kind of insecticides used. Although cotton in all insecticide treatments produced finer fiber in one year, the length, strength, and elongation were not affected in either year.

SUMMARY

Cotton planted on May 15-16 produced fiber of higher quality than cotton planted on April 15-16 or May 1-2. In 1959, the yield of Stoneville 3202 cotton was the same regardless of planting date. In 1960, Stardel cotton planted May 15-16 produced more seed cotton than that planted April 15-16 or May 1-2. Cotton planted May 1-2 produced more seed cotton than that planted on April 15-16.

Fiber quality of Coker 100 WR cotton planted in 1956 was the same when produced from plants deflorated 0, 3, and 7 weeks after fruiting began. In 1958, Stardel cotton deflorated for 7 weeks after fruiting began produced fiber significantly lower in length and fineness than that deflorated for 0 and 3 weeks. In 1959, Stoneville 3202 cotton fiber was equal in quality when deflorated for 0 and 3 weeks after fruiting began, but plants deflorated 7 weeks produced fiber significantly higher in strength and lower in fineness. Deltapine 15 cotton was significantly lower in fineness for plants deflorated 7 weeks. Fiber length and strength were not affected by defloration of plants.

In 1960, Stardel cotton fiber length and non-lint content were not affected by defloration treatment. Strength of fiber was significantly higher from plants which were deflorated for 4 and 5 weeks after fruiting began. Significant differences occurred for fiber fineness and elongation where plants were deflorated 7 consecutive weeks.

In 1956, the Coker 100 WR variety yielded the same amount of seed cotton in treatments with no fruit removed as in those with fruit removed for 3 and 7 weeks after fruiting began. In 1958, Stardel cotton deflorated for 3 weeks after fruiting began yielded significantly more

seed cotton than that not deflorated at all or that deflorated for 7 weeks. In 1959, Stoneville 3202 and Deltapine 15 cotton not deflorated and that deflorated 3 weeks after fruiting began yielded significantly more seed cotton than that deflorated for 7 weeks. In 1960, Stardel cotton deflorated 1 to 7 weeks after fruiting began yielded significantly more cotton than that which was allowed to retain all fruit possible. Plants deflorated 4 and 5 weeks after fruiting began yielded the greatest amount of seed cotton.

There were no differences in fiber quality of cotton protected by various insecticides and schedules of applications in 1959 and 1960. Fiber from cotton receiving protection from insects beginning at plant emergence and continuing to maturity was the same as that which received protection only after boll weevil infestation reached 25 per cent of the squares punctured.

In 1959, there was a difference in yield of seed cotton where insect control was accomplished as compared to no control. In 1960, no insect control and the application of toxaphene-DDT (2 pounds + 1 pound per acre) beginning when 25 percent of the squares were punctured yielded less seed cotton than all other insecticide treatments.

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A Study of Fiber Quality In Advanced Cotton Strains

Lucille Finley, Ferd W. Self and Neva F. Olsen

Louisiana State University and
Agricultural and Mechanical College
Agricultural Experiment Station
Charles W. Upp, Director

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A Study of Fiber Quality in Advanced Cotton Strains

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LUCILLE FINLEY,[1] FERD W. SELF,[2] AND NEVA F. OLSEN[3]

Introduction

Cotton ranks first among field crops as a source of total cash farm income for Louisiana *(6)*.[4] The economic value of cotton to the producer is determined by quality of the raw fiber. Factors which affect the quality of fiber properties include varietal characteristics, environmental factors, and cultural practices.

Fiber properties have a direct relationship to the rate of spinning efficiency. Cotton spinners have emphasized the need for fiber having desirable length, strength, fineness, and maturity to permit an increase in spinning rate. In recent years the increased speed of spinning cotton has been estimated at approximately 30 percent.

Improvement of inherent fiber properties begins by genetically controlling natural variation among selected individuals within component lines and recombining or massing them to develop a variety possessing satisfactory performance in the field and uniformity in mill processing. "A cotton variety is not a pure single strain which produces an exact copy of itself in each successive generation" *(5)*. Although the physical properties of length, strength, fineness, and elongation are recognized as heritable traits, a variety or advanced strain may be affected in level of expression of these traits by the influence of environmental factors.

Cotton fiber is recognized as a basic structural element highly useful for textile purposes. Study of this basic structural element is needed to establish the relationships of its geometric properties of length and fineness, and its mechanical properties of strength, elongation, and resilience to its performance in spinning, weaving, finishing, and serviceability of the end product.

Review of Literature

Several investigators have reported a significant relationship between the physical properties of cotton fiber and yarn and fabric quality.

The research of Fiori, *et al.* *(2)* pointed out that cotton fiber strength has a critical relationship to strength of yarn and fabric. Fiber strength, fineness, and length were properties which contributed most to yarn strength. Yarn strength was cited as the principal criteria used for determining yarn quality. Stronger yarns were produced from high-strength cottons than from low-strength cottons for the given yarn numbers and twist setting. According to Sands, *et al.* (*1*), the strongest fibered cotton, selected at three strength levels, produced the strongest fabric in the gray, bleached, and bleached and dyed state for fabric tested in the warp direction. The authors suggest that the potential fiber strength was not realized in the filling yarns because the low spinning twist used did not produce the necessary interfiber bonding.

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[1] Assistant Professor, Home Economics.

[2] Associate Professor, Agronomy.

[3] Instructor, Home Economics.

[4] Italic numbers in parentheses refer to Literature Cited, page 12.

Strength of yarn produced from blends of high-strength and low-strength fiber was in direct proportion to the percentage of the strong and weak fiber, according to Sands, *et al.* (*3*). Yarn strength was studied for fiber blended in ratios of 25/75, 50/50, and 75/25 for strong and weak fiber. The two controls (100% strong fiber cotton and 100% weak fiber cotton) and 50/50 blend were processed into an 80 x 80 print cloth, warp (30/1, 20 tex) and filling (40/1, 15 tex). Fiber bundle strength of cottons was directly related to warp breaking strength of fabric in the gray; scoured, bleached; bleached, mercerized, and dyed; bleached, mercerized, dyed, and resin treated. A direct relationship was found between fiber bundle strength and the strip breaking strength of warp and filling treated through bleaching, mercerizing, and dyeing.

Fiber length and fineness contribute to the frictional characteristics of fiber essential for satisfactory drafting operations. Length, fineness, and maturity are related to efficiency of the cleaning process and the amount of nep formation, according to Fiori, *et al.* (*2*).

A direct relationship was shown between elongation of fiber and elongation of fabric as reported by Sands, *et al.* (*3*).

Rebenfeld's (*5*) work has further shown the relationship existing between quality of fiber and performance of yarn and fabric. The rate of ends down in spinning, roving strength, and yarn uniformity was largely determined by fiber length and fiber length distribution. Strength and elongation of the yarn at break were associated with fiber strength and extensibility. Flex-abrasion resistance of cotton fabric was directly related to fiber stiffness. Tear resistance of fabric was found to depend on the extension of break of the yarns and was associated with extensibility of fibers.

Spinning efficiency of a cotton has been closely associated with staple length.

Materials and Methods

Purpose of this experiment was to determine whether cotton plants selected for conformation to a pre-determined level of fiber properties—length, strength, fineness, and elongation—could be sustained over a three-year period and if these properties were correlated with yield of lint per acre and other cotton plant characters. The effect of a genetic advance in any of these properties would be of particular interest to producers.

In 1956 and 1957 strains of highly inbred lines were selected for mechanical mixing and were increased without further selections in 1958, 1959, and 1960. Plants were selected and tested to meet a level of fiber length, strength, fineness, and elongation according to the following specifications: length, 1.06-1.09 (upper half mean in inches); strength, Stelometer, 19-20 grams per tex; Pressley, 85-90 thousand p.s.i.; fineness, 4.3-4.9 micronaire units; elongation, 7.0-7.9 percent. These fiber specifications are suitable for a wide group of cotton textiles. The original phenotype was developed by multiplying strain mixes on an isolated plot at Bossier City, Louisiana. The selected strains were multiplied in areas considered to be relatively low for natural crossing. Duncan (*4*) reported that the influence of natural selection accounted for an increase in lint percent and fiber and yarn strength for four-generation cottons multiplied in an environment of high natural crossing at Knoxville, Tennessee.

The strains and combinations used in this experiment were field tested in 1960, 1961, and 1962 at three Agricultural Experiment Stations, located at St. Joseph, Lecompte, and Bossier City, Louisiana, to determine whether a genetic advance occurred for fiber length (upper half mean), strength, fineness, and elongation and certain production and plant characters including yield, boll size, lint percent, and staple length. Land preparation, fertilization, and insect control practices used at each station were those recommended by the Louisiana Agricultural Experiment Station. Fiber samples were selected from two of the five plots planted in a randomized block design. The 100-boll samples were hand harvested from two replications from each experiment. Plants were harvested when approximately 60 percent of the bolls were open. All samples were picked on the same day to remove any variation due to date of harvest.

The experimental cottons were designated as advanced strain materials, LaES-56, 57, 58, 59, and 60, respectively, but all of these cottons were not tested in all years because of certain unforeseen conditions. LaES-59 cotton was tested at the three locations for all years. The mean fiber properties for cottons LaES-56, 57, 58, and 60 by year and station appear in Appendix I.

Stardel and Deltapine 15 were included as commercial checks in the experiment. Deltapine 15 was from registered seed produced in the previous year by a commercial firm. Stardel was grown from registered seed which had been produced on an isolated plot at Bossier City, Louisiana.

Fiber analyses were made in the textile research laboratory at Louisiana State University. All samples were treated under controlled conditions of humidity and temperature for at least 24 hours prior to testing. Fiber length, upper half mean, expressed as decimal fractions of an inch, was measured on the servo fibrograph. Fiber fineness was expressed as micronaire readings indicating the resistance to passage of air through a 50-grain plug of cotton in a fixed chamber. Fiber strength, expressed as an index at 0 gauge, was measured by the Pressley fiber strength tester, and as grams per tex at ⅛ inch gauge measured by the Stelometer, a pendulum fiber strength tester. Elongation was expressed as percent stretch or extension of the fiber occurring before break at ⅛ inch gauge on the pendulum type tester.

The data were treated by analysis of variance for appropriate comparisons among Stardel, Deltapine 15, and LaES-59 cottons by station and year for each of the fiber properties and plant characters.

Results and Discussion

Mean values of fiber properties for Stardel, Deltapine 15, and LaES-59 cottons are shown in Table 1. The differences between cottons as measured by the "F" test for each fiber property are shown in Table 2 and calculated yarn strength is shown in Table 3. Differences for fiber

TABLE 1.—Mean of Fiber Properties for Advanced Strains and Two Commercial Varieties by Years and Locations

		St. Joseph			Lecompte			Bossier City		
Property	Variety	1960	1961	1962	1960	1961	1962	1960	1961	1962
Strength (Pressley index 0 gauge)	Stardel	8.38	7.76	9.18	8.41	8.32	8.96	8.32	8.08	8.67
	DPL 15	7.32	7.37	8.36	7.76	7.44	7.88	7.29	7.50	8.25
	LaES-59	8.53	7.96	8.86	8.16	8.03	8.74	8.26	8.17	8.83
Strength (Stelometer grams/tex ⅛ gauge)	Stardel	19.51	19.32	22.68	18.83	20.25	19.58	20.62	21.18	20.39
	DPL 15	17.33	18.62	21.64	18.45	19.51	20.13	16.92	17.63	19.62
	LaES-59	19.31	19.39	22.47	19.12	19.31	21.26	20.04	19.67	20.36
Elongation (Percent)	Stardel	6.7	6.1	5.8	6.8	5.9	6.1	7.3	7.0	5.2
	DPL 15	8.3	8.2	7.1	7.9	7.7	7.3	9.8	8.2	7.2
	LaES-59	6.9	6.4	5.9	6.6	6.1	5.7	7.1	7.0	5.4
Fineness (Micronaire units)	Stardel	5.17	4.20	4.94	4.82	4.33	4.81	5.09	4.66	4.84
	DPL 15	5.08	4.21	4.94	4.33	4.01	4.52	4.75	4.47	4.55
	LaES-59	5.15	4.30	4.80	4.92	4.44	4.76	4.92	4.69	4.59
Length (UHM inches)	Stardel	1.12	1.19	1.09	1.04	1.15	1.03	1.14	1.15	1.01
	DPL 15	1.13	1.16	1.09	1.03	1.13	1.08	1.10	1.14	1.04
	LaES-59	1.12	1.18	1.08	1.03	1.16	1.06	1.14	1.12	1.03
Yield (Pounds lint per acre)	Stardel	1108	1159	1040	1141	830	1111	1214	820	378
	DPL 15	1187	1305	1083	1226	747	971	1136	750	347
	LaES-59	1075	1353	1098	1137	769	1128	1338	776	372
Boll Size (Average weight grams)	Stardel	5.65	5.90	5.35	5.45	5.70	5.05	6.05	5.20	4.95
	DPL 15	6.35	5.90	5.30	5.80	5.90	5.65	6.80	5.45	5.15
	LaES-59	5.80	5.66	5.40	5.75	5.75	5.20	6.10	5.10	5.05
Lint Percent	Stardel	40.15	38.30	38.55	40.75	37.45	39.10	39.85	40.30	40.15
	DPL 15	40.30	38.75	39.70	41.00	36.55	39.10	40.05	40.35	39.75
	LaES-59	39.85	39.60	38.75	41.70	37.25	38.75	39.40	40.45	38.85
Staple Length (32's inch)	Stardel	35.0	35.0	34.3	34.0	35.5	33.5	34.0	34.0	34.0
	DPL 15	34.5	35.0	34.7	33.5	34.5	34.0	34.0	34.0	34.0
	LaES-59	34.7	34.3	34.6	33.8	34.5	33.9	34.2	34.1	33.7

properties by main effects and interaction effects are shown in Table 4. Correlation coefficients are shown in Table 5.

Fiber Strength—Pressley index showed a highly significant difference for variety and year. LaES-59 and Stardel were stronger than Deltapine 15 in all years and at all locations. A highly significant difference was found between Stardel plus LaES-59 and Deltapine 15, as shown in Table 2. Pressley strength in thousand p.s.i. placed LaES-59 and Stardel above 85.0 thousand p.s.i., established as the lower limit for strength in making the original plant selections. Deltapine 15 attained the minimum level of 85.0 thousand p.s.i. in the third year only at all locations. The strength of Stardel ranged between 87.0 and 99.2 thousand p.s.i.

Fiber strength tested at 1/8 inch gauge by the Stelometer showed a significant to highly significant difference by location, year, and variety, respectively. LaES-59 and Stardel exceeded the minimum specifications

TABLE 2.—Differences Between LaES-59, Stardel, and Deltapine 15 by Fiber Property as Measured by the "F" Test

Property	Source	d.f.	S.S.	M S.	F
Strength (Pressley index 0 gauge)	Varieties	2	6.5826	3.2913	112.7158**
	LaES-59 vs. Stardel	1	.0324	.0324	1.1096
	LaES-59 + Stardel vs. DPL 15	1	6.5712	6.5712	225.0411**
	error	18	.5265	.0292	
Strength (Stelometer grams/tex 1/8 gauge)	Varieties	2	20.8165	10.4082	17.6380**
	LaES-59 vs. Stardel	1	.2304	.2304	.3904
	LaES-59 + Stardel vs. DPL 15	1	20.5932	20.5932	34.8979**
	error	18	10.6226	.5901	
Elongation (Percent)	Varieties	2	32.3400	16.1700	238.4956**
	LaES-59 vs. Stardel	1	.0081	.0081	.1195
	LaES-59 + Stardel vs. DPL 15	1	32.4723	32.4723	478.9425**
	error	18	1.2200	.0678	
Fineness (Micronaire units)	Varieties	2	.5236	.2618	18.7000**
	LaES-59 vs. Stardel	1	.0081	.0081	.5786
	LaES-59 + Stardel vs. DPL 15	1	.5043	.5043	36.0214**
	error	18	.2536	.0140	
Length (UHM inches)	Non-significant "F"				
Yield (Pounds lint per acre)	Non-significant "F"				
Boll Size (Average weight gm.)	Varieties	2	1.1400	.5700	109.6154**
	LaES-59 vs. Stardel	1	.0225	.0225	4.3269
	LaES-59 + Stardel vs. DPL 15	1	1.1163	1.1163	214.6731**
	error	18	.0934	.0467	
Lint Percent	Non-significant "F"				
Staple Length (32's inch)	Non-significant "F"				

* Significant at .05% level.
**Significant at .01% level.

of 18.00 grams per tex and were stronger than Deltapine 15. The difference was highly significant. There was no difference between Stardel and LaES-59. An increase in strength occurred for Deltapine 15 by year at each location. The level of strength increased for all the cottons in the third year of the experiment, as determined by both laboratory methods.

Fiber Length—Upper half mean showed a similar response in length among varieties within year and location and a highly significant difference between year and location. Fiber was longer for the cottons at all locations in 1961 and slightly longer in 1960 than in 1962. The highly consistent response in length among cottons indicates that environmental factors possibly expressed greater influence than varietal traits. There was no significant difference in length between LaES-59, Stardel, and Deltapine 15 (Table 2). Fiber length for all cottons was below the minimum specification of 1.06 U.H.M. only in 1960 at Lecompte, and in 1962 at Bossier City.

Fiber Fineness—A highly significant difference was shown among varieties, years, and locations (Table 4). The level of fineness was higher for Stardel and LaES-59 than for Deltapine 15 by year within location. A highly significant difference in fineness was found between Stardel plus LaES-59 and Deltapine 15 (Table 2). All varieties produced finer fiber in 1961. In certain locations and in certain years fiber fineness exceeded the upper limit of 4.9 micronaire as set in the original specifications.

Fiber Elongation—A highly significant difference was shown among varieties and years. Fiber elongation decreased for each cotton by year within location. LaES-59 and Stardel were lower in elongation than Deltapine 15 by a highly significant difference. Higher elongation for Deltapine 15 in this experiment was attributed to varietal difference. A

TABLE 3.—Calculated Strength in Pounds of 22's Yarn Using 3 Factors of Cotton Quality

Variety	Year		
	1960	1961	1962
Stardel	122.32	129.72	119.49
DPL 15	120.78	122.77	118.74
LaES-59	120.88	128.34	115.98
	Location		
	St. Joseph	Lecompte	Bossier City
Stardel	127.28	122.92	121.30
DPL 15	121.30	119.48	117.35
LaES-59	126.28	120.75	122.60
	All Locations and All Years		
Stardel	123.88		
DPL 15	119.65		
LaES-59	123.60		

decrease from the pre-selected level for fiber elongation occurred each year.

Predicted Yarn Strength—Strength was calculated in pounds for 22's yarns for each cotton by year, location, and for all locations and years (Table 3) using an empirical equation for three factors of cotton quality (7). In 1961 yarn strength was higher and may have been influenced by fiber length. In 1960 and 1961 predicted yarn strength for Stardel was slightly higher than for LaES-59 and both were better than the strength of Deltapine 15. Calculated yarn strength for Stardel and LaES-59 by location was very close, and both were above Deltapine 15. Yarn strength of all cottons was higher at St. Joseph than at either Lecompte or Bossier City, Louisiana. Calculated yarn strength by location and years ranked the cottons in the following order: Stardel, 123.88; LaES-59, 123.60; Deltapine 15, 119.65.

Plant Characters—The strains and commercial varieties did not show a significant difference for yield in pounds of lint per acre or for staple length in 32's inch, as shown in Table 2.

The mean weight in grams for boll size of LaES-59 strains did not differ significantly from the mean of Stardel. A significant difference

TABLE 4.—Calculated "F" Values for Main Effects and Interaction Effects of Mean Fiber Properties of LaES-59, Stardel, and Deltapine 15

Property	Variety	Year	Location	Years x Location	Variety x Location	Year x Variety	Years x Location x Variety
Strength (Pressley index 0 gauge)	112.716**	100.060**	0.287	4.327*	1.529	1.488	2.689*
Strength (Stelometer grams/tex ⅛ gauge)	17.638**	71.560**	4.056*	15.187**	3.960*	2.570	1.090
Length (UHM inches)	0.000	106.000**	30.260**	15.250**	0.500	2.500	14.000**
Fineness (Micronaire units)	18.700**	42.024**	6.714**	6.229*	5.943**	2.478	0.178
Elongation (Percent)	238.495**	69.364**	8.182	8.454**	2.833	0.666	3.833*
Yield (Pounds lint per acre)	0.509	16.106**	18.279**	13.508**	1.038	0.217	0.995
Boll Size (Average weight grams)	109.615**	7.986*	0.386	2.041	0.059	0.204	0.112
Lint Percent	0.103	13.540**	3.770*	9.635**	0.857	0.967	0.472
Staple Length (32's inch)	0.000	0.000	18.182**	22.727**	15.625**	6.250**	6.250**

* Significnat at .05% level.
**Significant at .01% level.

was found between Deltapine 15 and Stardel plus the advanced strain. Deltapine 15 produced larger bolls for the three-year average. The three-year average yield of lint per acre did not show a significant difference among cottons.

Average lint percent was not significantly different among cottons.

LaES-59, Stardel, and Deltapine 15 had the same average staple length –34.0/32 of an inch.

The properties under observation did not indicate a high correlation. Fiber strength indexes as measured by Pressley and Stelometer were negatively correlated with upper half mean length and elongation of fiber. Fineness showed a positive correlation with strength but a negative correlation with upper half mean length. This may be due to the influence of fiber maturity, which is not shown in the comparison.

A positive correlation was shown between yield of lint per acre and boll size. Lint percent indicated a negative correlation with upper half mean length and a positive correlation with fiber fineness. The two measurements of length of fiber–upper half mean and staple length –indicate there is correlation with yield of lint. Lint percent showed negative correlation with staple length and upper half mean length.

TABLE 5.–Correlation Coefficients Among the Properties of Strength, Upper Half Mean Length, Fineness, Elongation, Yield of Lint per Acre, Boll Size, Lint Percent, and Staple Length of Strains and Two Commercial Varieties Grown in Advanced Strain Experiments at St. Joseph, Lecompte, and Bossier City, Louisiana in 1960, 1961, and 1962

Property	Strength (Stelometer grams/tex ⅛ gauge)	Length (UHM inches)	Fineness (Micronaire units)	Elongation (Percent)	Yield (Pounds lint per acre)	Boll Size (Average wt. grams)	Lint Percent	Staple Length (32's inch)
Strength (Pressley index 0 gauge)	.5641*	–.4113*	.3556*	–.5107*	–.0721	–.2831*	.0493	–.1817
Strength (Stelometer grams/tex ⅛ gauge)		.1406	.1421	–.4130*	–.0177	–.2429*	–.1727	–.0034
Length (UHM inches)			–.4223*	.2033*	.2152*	.2849*	–.3823*	.5158*
Fineness (Micronaire units)				–.0492	.1710	.0690	.3834*	–.2159*
Elongation (Percent)					.2064*	.2445*	.1558	.0958
Yield (Pounds lint per acre)						.3922*	.1085	.1521
Boll Size (Average weight grams)							–.1061	.2061*
Lint Percent								–.3192*

* Significant at .05% level.

The plant breeder would be interested in correlation indexes between properties when improvement in the quality of cotton is under consideration.

Summary

A highly significant difference was found between Stardel plus LaES-59 and Deltapine 15 in fiber strength, fineness, and elongation.

Fiber strength of Stardel and LaES-59 was higher than fiber strength of Deltapine 15. Stardel and LaES-59 exceeded the minimum specifications in all years of the experiment. Stronger fiber in the third year suggests the influence of environmental factors.

Fiber fineness was found to be generally in the upper limits for the fineness specification. Each cotton produced finer fiber in 1961 at all locations. Difference among cottons was significant.

Fiber length was not different among the varieties within year by location. Longer fiber was produced by all cottons in 1961.

A progressive decrease in percent fiber elongation occurred for each cotton by year at each location. Deltapine 15 maintained the minimum level of 7.0 percent. The property of elongation was not maintained at the selected level for LaES-59 and Stardel.

Except for elongation, the performance of LaES-59, based on selected specifications for fiber length, strength, and fineness, was controlled and/or maintained by mechanical mixing, although the experiment was conducted in areas considered to be relatively low for natural crossing.

Quality of the cottons was further projected by calculating strength for 22's yarn using three factors of cotton quality. LaES-59 was comparable to Stardel, and both were higher than Deltapine 15.

Deltapine 15 produced larger bolls for the three-year period than the other cottons.

A varietal difference in average staple length was not shown among the cottons.

LaES-59 yielded slightly more pounds lint per acre than Stardel and Deltapine 15.

Correlation coefficients showed a positive relationship between yield of lint and boll size; and between lint percent and fiber fineness. Negative correlation coefficients were shown between upper half mean length and fiber elongation; and between fineness and lint percent.

APPENDIX I.—Mean of Fiber Properties by Years and Locations for Advanced Strains of LaES-56, LaES-57, LaES-58 and LaES-60

		St. Joseph			Lecompte			Bossier City		
Property	Variety	1960	1961	1962	1960	1961	1962	1960	1961	1962
Strength (Pressley index 0 gauge)	LaES-56	..	8.22	8.94	8.44	8.02	9.02	..	..	..
	LaES-57	..	8.32	8.88	8.77	..	9.50	..	..	..
	LaES-58	8.28	8.10	8.86	..	7.95	8.78	..	8.42	8.80
	LaES-60	..	7.83	8.84	..	..	..	..	..	..
Strength (Stelometer grams/tex 1/8 gauge)	LaES-56	..	19.51	23.05	19.04	19.42	19.25	..	..	..
	LaES-57	..	20.11	22.05	19.21	..	21.94	..	..	..
	LaES-58	18.68	19.25	22.94	..	19.24	21.16	..	20.33	20.58
	LaES-60	..	18.44	22.07	..	..	..	..	..	..
Elongation (Percent)	LaES-56	..	6.1	6.0	6.2	5.9	6.4	..	..	..
	LaES-57	..	6.3	6.1	6.0	..	5.4	..	..	..
	LaES-58	6.8	6.3	5.5	..	5.9	5.6	..	6.8	5.2
	LaES-60	..	6.2	5.8	..	..	..	..	..	..
Fineness (Micronaire units)	LaES-56	..	4.38	4.74	5.06	4.50	4.84	..	..	..
	LaES-57	..	4.52	4.61	5.02	..	4.66	..	..	..
	LaES-58	5.08	4.41	4.89	..	4.59	4.69	..	4.84	4.64
	LaES-60	..	4.50	5.05	..	..	..	..	..	..
Length (UHM inches)	LaES-56	..	1.18	1.10	1.04	1.15	1.02	..	..	..
	LaES-57	..	1.16	1.09	1.04	..	1.10	..	..	..
	LaES-58	1.14	1.18	1.08	..	1.15	1.06	..	1.12	1.02
	LaES-60	..	1.20	1.09	..	..	..	..	..	..
Yield (Pounds lint per acre)	LaES-56	..	1228	1116	1245	899	1155	..	..	..
	LaES-57	..	1260	967	1208	..	1188	..	..	..
	LaES-58	1021	1330	1004	..	723	1029	..	697	364
	LaES-60	..	1056	1263	..	..	..	..	..	..
Boll Size (Average weight grams)	LaES-56	..	6.17	5.09	5.91	5.81	5.03	..	..	..
	LaES-57	..	5.94	4.85	5.69	..	5.80	..	..	..
	LaES-58	5.17	5.00	5.44	..	5.90	5.16	..	5.30	5.08
	LaES-60	..	5.72	5.59	..	..	..	..	..	..
Lint Percent	LaES-56	..	38.06	37.84	40.53	37.76	39.43	..	..	..
	LaES-57	..	39.11	38.27	40.61	..	38.95	..	..	..
	LaES-58	40.00	40.04	38.97	..	37.28	38.74	..	40.49	38.91
	LaES-60	..	37.84	39.21	..	..	..	..	..	..
Staple Length (32's inch)	LaES-56	..	35.1	34.2	33.9	34.6	34.0	..	..	..
	LaES-57	..	35.1	34.5	33.9	..	34.0	..	..	..
	LaES-58	34.5	35.0	34.2	..	35.3	34.0	..	34.0	34.0
	LaES-60	..	35.0	34.4	..	..	..	..	..	..

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EPTEMBER 1964

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BULLETIN NO. 586

Consumer Preference For . . .
BROILER PIGMENTATION
In New Orleans, Louisiana

John Heffner
Ewell P. Roy
B. H. Davis
W. B. Hilton

DEPARTMENT OF AGRICULTURAL ECONOMICS
AND AGRIBUSINESS
AND
DEPARTMENT OF POULTRY SCIENCE, COOPERATING

Louisiana State University and
Agricultural and Mechanical College
Agricultural Experiment Station
Doyle Chambers, Director

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Consumer Preference for Broiler Pigmentation in New Orleans, Louisiana

JOHN F. HEFFNER, EWELL P. ROY, B. H. DAVIS AND W. B. HILTON[1]

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INTRODUCTION

Commercial broiler production in Louisiana increased from less than one million pounds per year during the period 1934-1939 to over 93 million pounds in 1963. The value of broilers produced in Louisiana in 1963 amounted to $13,048,000, or approximately 3.0 per cent of the total cash farm income received by Louisiana farmers. Over a 12-year period, chickens and broilers increased from a ranking of 14th in 1951 to a ranking of 7th in 1962 in cash receipts from farm products in Louisiana.[2]

To support this increase in broiler production in Louisiana certain marketing adjustments are needed. This includes widened market areas and better processing and merchandising practices to meet consumer needs and to increase consumption. It is thus important to determine certain characteristics of consumers' preference for broilers. This is a report of the results of a study conducted in New Orleans, Louisiana, in 1964, concerning one aspect of consumer preference—consumers' preference for various levels of skin pigmentation in broilers.[3]

REVIEW OF LITERATURE

Raskopf, Kidd, and Goff[4] reported that in a grocery store experiment where broilers of three different degrees of skin pigmentation were displayed for sale at the same time, there was a significant difference in consumer acceptance in favor of the more deeply pigmented bird.[5] Consumers selected the more deeply pigmented birds 43 per cent of the time. This experiment also revealed that in a display of broilers where only one degree of skin pigmentation was offered for sale during randomized 20-minute intervals, no significant difference was found in the percentage of broilers sold. The results of this study indicated that 99 per cent of the customers accepted broilers with any degree of pigmentation as long as there was a choice as to weights and as long as the birds rated high in quality.

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[1] J. F. Heffner, Instructor, and Ewell P. Roy, Associate Professor, Department of Agricultural Economics and Agribusiness; B. H. Davis, Associate Professor, and W. B. Hilton, Assistant Professor, Department of Poultry Science.

[2] United States Department of Agriculture, *1963 Broiler Production* (Alexandria, Louisiana: Statistical Reporting Service, February 6, 1964).

[3] Skin pigmentation is the level of yellow coloring of the skin of broilers.

[4] B. D. Raskopf, I. H. Kidd, and O. E. Goff, *Effects of Diets Containing Milo on Broilers and Consumer Acceptance of Broilers Differing in Degree of Skin Pigmentation,* The University of Tennessee Agricultural Experiment Station Bulletin 324, Knoxville, Tennessee, April 1961.

[5] Significance was determined at the 95 per cent level, which means the order of acceptance could have occurred by chance 1 out of 20 times.

Courtenay and Branson[6] in 1962 found that more than two out of three housewives preferred chickens with some degree of pigmentation and that most preferred a medium to moderate yellow color. They also found that non-Caucasian housewives preferred a greater degree of pigmentation than did the Caucasians. They also reported that as the socioeconomic level of housewives increased, the skin pigmentation preference moved toward one of moderate to a light yellow pigmented bird. Most of the housewives preferred a certain skin color because of its good appearance or because it denoted to them the flavor, tenderness, and amount of fat that they desired in a chicken.

Mountney, Branson, and Courtenay[7] reported in 1959 that most chain food store shoppers look for six things when buying chicken. They are, in order of importance, skin color, plumpness, weight, freshness, cleanliness, and brand name. Nearly half (46 per cent) of the shoppers indicated that skin color was their first or second consideration when purchasing a chicken. A yellow colored bird was preferred by about the same number of shoppers as those who chose light colored birds. A few shoppers preferred a pink colored bird. It was believed that some housewives chose yellow colored birds because they associated the yellow color with a high quality broiler. Some of the younger housewives may have associated the yellow color with fat and for this reason chose the lighter colored broilers.

Davis[8] in 1963 found that consumers preferring pigmented birds gave the following as reasons for doing so: (1) yellow pigment means the birds have more flavor, (2) yellow pigment means the birds are in good health, (3) yellow pigmented birds contain more fat, and (4) yellow pigment means the birds are more tender.

Davis also found that consumers discriminating against the pigmented birds did so for the following reasons: (1) yellow means the birds are too fat, (2) yellow looks artificial, (3) yellow means older birds, and (4) white skin looks cleaner.

---

[6] H. V. Courtenay and B. E. Branson, *Consumers Image of Broilers,* Texas Agricultural Experiment Station Bulletin 989, Texas A. & M. University, College Station, Texas, April 1962.

[7] G. J. Mountney, B. E. Branson, and H. V. Courtenay, *Preference of Chain Food Store Shoppers in Buying Chickens,* Texas Agricultural Experiment Station publication No. MP-348, Texas A. & M. University, College Station, Texas, April 1959.

[8] Davis, B. H., "How Do Consumers React to Broiler Pigmentation?" *Broiler Business,* Cullman, Alabama, July 1963.

METHODOLOGY

Growing the Broilers

Three different groups of birds were grown on the Louisiana State University Poultry Farm in Baton Rouge, Louisiana. One group was produced for the purpose of yielding heavily pigmented skin color while another group was produced to yield moderately pigmented skin color. The remaining group was produced to yield no skin color, or a white skin.

Broilers having *moderate* pigment were fed the following basic ration:

BASIC RATION

Ingredient	*Pounds*
Yellow corn meal	57.0
Soybean meal (50%)	27.5
Tallow	5.0
Fish meal	3.0
Alfalfa leaf meal	3.0
Dicalcium phosphate	2.0
Oyster shell flour	1.0
Salt	0.5
Vitamin Premix	1.0
Total	100.0

To produce the *heavily* pigmented broilers, gluten feed meal replaced half of the yellow corn meal in the basic ration and 7 grams of xanthophyll per ton of ration were added.

To produce birds with *no* pigment, milo was substituted for the yellow corn meal and the alfalfa leaf meal in the basic ration. Tallow was increased to the level of 5.5 pounds per 100 pounds of ration to maintain the same level of fat fed to all the broilers receiving the three diets.

Small differences were found in the average body weight of broilers receiving the three diets. Also, small differences were found in the average feed efficiency of birds fed the three different diets (Table 1).

TABLE 1.—Effects of Feeding Diet on Body Weight, Feed Efficiency, and Pigmentation, Baton Rouge, Louisiana, 1964

Diet	Average body weight per broiler, lbs.	Feed efficiency (lbs. feed/lb. broiler)	Pigmentation level
Basic diet	3.79	2.65	Moderate
Milo for corn & alfalfa meal	3.67	2.52	None
Corn gluten meal for half yellow corn, plus 7 grams xanthophyll per ton	3.74	2.63	Heavy

Conducting the Store Test

To conduct the consumer preference test, two grocery supermarkets were selected, each in a middle income neighborhood in New Orleans, Louisiana. These grocery supermarkets were selected because they were large enough to sell approximately 1,000 broilers each over a three-day period (Thursday, Friday, and Saturday).

Broilers of three different levels of skin pigmentation (no pigment, moderate pigment, and heavy pigment) were used to determine consumer preferences for skin pigmentation.

The matched-lot test technique was employed in conducting the experiment. The broilers were displayed in the meats area of the supermarket normally reserved for broilers. Equal numbers of whole birds of different degrees of skin pigmentation were displayed at the same time. The birds of different levels of skin pigmentation were separated by portable partitions. In both stores, as birds were sold, they were replaced with like broilers so that the customer chose from a full display at all times. Consumers' purchases were observed and recorded in both stores on all days of the test.

RESULTS OF THE STORE STUDY

Characteristics of Respondents

The race and sex of each customer was recorded for statistical analysis. The predominant consumer group in both stores was white females. They constituted approximately 83.5 per cent of all customer observations recorded, followed by white males, 12.3 per cent; colored females, 3.4 per cent; and colored males, 0.8 per cent.

Results From Store No. 1

In Store No. 1, 1,410 birds representing all three degrees of pigment were offered for sale during the test period. Store No. 1 conducted a 19-cent-per-pound special sale on broilers at the time of the experiment. For this reason the average number of broilers purchased per customer (3.56) was higher than would normally have been expected.

The birds were packaged in transparent polyethelene bags, two whole birds per bag. Each package contained a label indicating the total weight, price per pound, and total price of the twin-packed broilers.

The preference shown by consumers purchasing broilers in Store No. 1 for the various levels of skin pigmentation was in the order of heavy, moderate, and none, as shown in Table 2.

Broilers with heavily pigmented skin were preferred by more cus-

TABLE 2.–Consumer Preferences for Broilers Having Various Levels of Skin Pigmentation, Store No. 1, New Orleans, Louisiana, March 1964

	Pigment level			
	Heavy	Moderate	None	Total
Consumers purchasing broilers	208	157	90	455
Broilers purchased[1]	701	463	246	1,410

[1] By request of some of the shoppers, some of the bags containing two birds were broken so that one broiler could be purchased.

tomers than any other pigment level. Of the consumers purchasing broilers, 208 (or approximately 46 per cent) bought heavily pigmented birds as compared with 157 (or 34 per cent) purchasing birds with moderate pigmentation and 90 (or 20 per cent) purchasing birds having no pigmentation.

Of the 1,410 broilers purchased during the experiment in Store No. 1, 701 (or approximately 50 per cent) were heavily pigmented, while 463 (or 33 per cent) were moderately pigmented and 246 (or 17 per cent) had no pigmentation.

Significant statistical differences existed between heavy and moderate pigment and also between pigment (heavy or moderate) and no pigment at the 99 per cent level of confidence. All of the significance tests were done by Chi-square analysis.[9]

Results From Store No. 2

In Store No. 2, 950 birds representing all three degrees of pigmentation were offered for sale during the test period. The broilers were priced at 25 cents per pound during the time of the experiment. The average number of broilers purchased in Store No. 2 was 2.15 per customer.

The birds were packaged in transparent polyethelene bags. One whole bird was included in each package. Each package contained a label indicating the total weight, price per pound, and total price of the broiler.

The preference shown by consumers purchasing broilers in Store No. 2 for the various levels of skin pigmentation was in the order of moderate, heavy, and none, as shown in Table 3.

Broilers with moderately pigmented skin were preferred by more customers in Store No. 2 than any other pigment level. Moderately pigmented birds accounted for 217 (or approximately 42 per cent) of the consumer purchases as compared with 165 (or 32 per cent) for heavy pigmentation and 132 (or 26 per cent) for birds having no pigmentation.

Of the 950 broilers purchased during the experiment in Store No. 2, 383 (or 40 per cent) were moderately pigmented, while 335 (or 35 per cent) were heavily pigmented and 232 (or 25 per cent) had no pigmentation.

TABLE 3.—Consumer Preferences for Broilers Having Various Levels of Skin Pigmentation, Store No. 2, New Orleans, Louisiana, March 1964

	Pigment level			
	Heavy	Moderate	None	Total
Consumers purchasing broilers	165	217	132	514
Broilers purchased	335	383	232	950

---

[9] Chi-square analysis for Store No. 1 is shown in Appendix Table 1. "Significance" at the 99 per cent level means the order of preference could have occurred by chance only 1 out of 100 times.

Significant statistical differences existed between heavy and moderate pigment and also between pigment (heavy or moderate) and no pigment at the 99 per cent level of confidence. All of the significance tests were done by Chi-square analysis.[10]

Preference Related to Sex

Preferences for various levels of broiler skin pigmentation were not significantly related to sex, as shown in Tables 4 and 5. Both sexes preferred approximately the same degree of pigmentation in broilers. There were no statistically significant differences (99 per cent level) between the preferences of male shoppers and the preferences of female shoppers in either store.[11]

TABLE 4.—Preferences for Various Pigment Levels in Broilers as Related to Sex, Store No. 1, New Orleans, Louisiana, March 1964

	Choice			
	Heavy	Moderate	None	Total
	— — — — —	— Number —	— — — — —	
Male	28	21	13	62
Female	180	136	77	393

TABLE 5.—Preferences for Various Pigment Levels in Broilers as Related to Sex, Store No. 2, New Orleans, Louisiana, March 1964

	Choice			
	Heavy	Moderate	None	Total
	— — — — —	— Number —	— — — — —	
Male	18	29	18	65
Female	147	188	114	449

Consumer Attitudes

Some of the consumers' reactions to pigmented birds were recorded in this study. The primary reasons given by the consumers against birds with no pigment were: (1) white color is associated with stewing hens, (2) white birds do not have enough fat. Those preferring pigmentation did so for the following reasons: (1) yellow pigment looks healthier, (2) yellow birds look bigger, (3) yellow pigmented birds look fatter, (4) yellow pigmented birds look prettier, and (5) yellow pigment indicates birds are of a higher grade.

The primary reason given by consumers against pigmentation was that the yellow color indicated the birds were too fat. Those preferring no pigment did so for the following reasons: (1 white color indicates the birds are milk fed, (2) white skin birds contain less fat, and (3) white birds look clean.

---

[10] Chi-square analysis for Store No. 2 is shown in Appendix Table 2.

[11] Chi-square analysis for various levels of skin pigmentation as related to sex is shown in Appendix Tables 3 and 4.

SUMMARY

Tests to determine consumer preferences for various levels of skin pigmentation in broilers were conducted in two grocery supermarkets, each in a middle income neighborhood in New Orleans, Louisiana, during 1964. Birds used in the study were grown on the Louisiana State University Poultry Farm in Baton Rouge. Equal numbers of whole birds of three different degrees of skin pigmentation (heavy, moderate, and none) were displayed at the same time in each store in a matched-lot test. The experiment was conducted over a three-day period (Thursday, Friday, and Saturday). The grocery supermarkets used in this study were selected because they were large enough to sell approximately 1,000 broilers each over the three-day period. For this reason both stores selected were located in middle income neighborhoods in New Orleans, Louisiana. Thus, the results reported in this study are based on purchases made by consumers shopping in these two middle income neighborhoods in New Orleans, Louisiana. Significant findings of this experiment are summarized as follows:

Store No. 1

The order of preference shown by consumers in Store No. 1 for the various levels of pigmentation was heavy, moderate, and none. Heavily pigmented birds accounted for approximately 46 per cent of the 455 consumer purchases recorded, as compared with 34 per cent for moderate pigment and 20 per cent for birds having no pigmentation. The differences among pigment levels were statistically significant at the 99 per cent level.[12]

Store No. 2

The order of preference shown by consumers in Store No. 2 for the various levels of pigmentation was moderate, heavy, and none. Moderately pigmented birds accounted for approximately 42 per cent of the 514 consumer purchases recorded, as compared with 32 per cent for heavy pigment and 26 per cent for birds having no pigmentation. The differences among pigment levels were statistically significant at the 99 per cent level.[13]

CONCLUSIONS

These results indicate that the consumer in these two middle income neighborhoods in New Orleans, Louisiana, has a definite preference for skin pigment in broilers (either heavy or moderate) as opposed to no pigment. However, preference as to the degree of pigmentation can be expected to vary from store to store.

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[12] See Appendix Table 1.

[13] See Appendix Table 2.

APPENDIX

APPENDIX TABLE 1.—Chi-Square Analysis of Various Broiler Pigment Levels, Store No. 1[1]

Pigment level	Actual sales	Theoretical sales	Deviation	Deviation²	Deviation² / Theoretical
Heavy	208	151.6	56.4	3180.96	20.98
Moderate	157	151.7	5.3	28.09	0.18
None	90	151.7	–61.7	3806.89	25.09
Total	455	455	0	-	46.25

[1] Table X^2, 2 d.f., 99% level is 9.210. *Significant* differences among pigment levels. Test of significance of Heavy vs. Moderate pigment: Table X^2, 1 d.f., 99% level is 6.635.

$$X^2 = \frac{(208 - 182.5)^2 + (157 - 182.5)^2}{182.5} = 7.126. \quad \textit{Significant.}$$

Test of significance of Heavy and Moderate vs. None:

$$X^2 = \frac{(367 - 303.3)^2}{303.3} + \frac{(90 - 151.7)^2}{151.7} = 38.47. \quad \textit{Significant.}$$

APPENDIX TABLE 2.—Chi-Square Analysis of Various Pigment Levels, Store No. 2[1]

Pigment level	Actual sales	Theoretical sales	Deviation	Deviation²	Deviation² / Theoretical
Heavy	165	171.3	-6.3	39.7	.23
Moderate	217	171.3	45.7	2088.5	12.19
None	132	171.4	-39.4	1552.4	9.06
Total	514	514	0	-	21.48

[1] Table X^2, 2 d.f., 99% level is 9.210. *Significant* differences among pigment levels. Test of significance of Heavy vs. Moderate: Table X^2, 1 d.f., 99% level is 6.635.

$$X^2 = \frac{(165 - 191)^2 + (217 - 191)^2}{191} = 7.08. \quad \textit{Significant.}$$

Test of significance of Heavy and Moderate vs. None:

$$X^2 = \frac{(382 - 342.6)^2}{342.6} + \frac{(132 - 171.4)^2}{171.4} = 13.59. \quad \textit{Significant.}$$

APPENDIX TABLE 3.—Chi-Square Analysis, Preferences for Various Levels of Skin Pigmentation in Broilers as Related to Sex of Customer, Store No. 1

	Heavy		Moderate		None		
Item	Observed	Expected	Observed	Expected	Observed	Expected	Total
Male	28	20.7	21	20.7	13	20.6	5.37
Female	180	131.0	136	131.0	77	131.0	40.78
Sum X^2	208	151.7	157	151.7	90	151.6	46.11
Pooled X^2							46.15
Difference X^2 (Heterogeneity)							0.04

Table X^2, 99% level, 2 d.f. is 9.210. Difference $X^2 = 0.04$. *Not Significant.*
Computations for X^2 values:

$$\text{Male} = \frac{(28 - 20.7)^2}{20.7} + \frac{(21 - 20.7)^2}{20.7} + \frac{(13 - 20.6)^2}{20.6} = 5.37.$$

$$\text{Females} = \frac{(180 - 131)^2}{131} + \frac{(136 - 131)^2}{131} + \frac{(77 - 131)^2}{131} = 40.78.$$

$$\text{Sum } X^2 = \frac{(208 - 151.7)^2}{151.7} + \frac{(157 - 151.7)^2}{151.7} + \frac{(90 - 151.6)^2}{151.6} = 46.11.$$

APPENDIX TABLE 4.—Chi-Square Analysis, Preferences for Various Levels of Skin Pigmentation in Broilers as Related to Sex of Customer, Store No. 2

	Heavy		Moderate		None		
Item	Observed	Expected	Observed	Expected	Observed	Expected	Total
Male	18	21.7	29	21.7	18	21.6	3.71
Female	147	149.7	188	149.7	114	149.6	18.32
Sum X^2	165	171.4	217	171.4	132	171.2	21.37
Pooled X^2							22.03
Difference X^2 (Heterogeneity)							0.66

Table X^2, 99% level, 2 d.f. is 9.210. Difference $X^2 = 0.66$. *Not Significant.*
Computations for X^2 values:

$$\text{Male} = \frac{(18 - 21.7)^2}{21.7} + \frac{(29 - 21.7)^2}{21.7} + \frac{(18 - 21.6)^2}{21.6} = 3.71.$$

$$\text{Female} = \frac{(147 - 149.7)^2}{149.7} + \frac{(188 - 149.7)^2}{149.7} + \frac{(114 - 149.6)^2}{149.6} = 18.32.$$

$$\text{Sum } X^2 = \frac{(165 - 171.4)^2}{171.4} + \frac{(217 - 171.4)^2}{171.4} + \frac{(132 - 171.2)^2}{171.2} = 21.37.$$

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BULLETIN NO. 587

nterregional Competition in Marketing Fresh Sweet Potatoes

JERRY M. LAW
HOMER G. PONDER

DEPARTMENT OF AGRICULTURAL ECONOMICS
AND AGRIBUSINESS
Louisiana State University and
Agricultural and Mechanical College
Agricultural Experiment Station
Doyle Chambers, Director

FOREWORD

Dramatic changes have occurred in the United States sweet potato industry over the past two to three decades. Some of the more striking changes have been in consumption, acreage, production, number of farms producing sweet potatoes, and geographic pattern of production.

These changes have had a major impact on the competitive positions of sellers in different producing areas. Farmers, shippers, and others selling sweet potatoes inevitably face the problem of adjusting to changes of this nature. Much of the information required for the most profitable solution to this adjustment problem is not readily available to sellers. Moreover, a procedure is lacking for making effective use of such information in determining needed adjustments.

This study involved the adaptation and application of a relatively new research procedure. It indicated that a *different* shipping pattern would have been more profitable to sweet potato shippers in 1958-59 than the one followed.

The important contribution to knowledge from the study consists of the adaptation and application of this procedure for use in making *current* decisions concerning best markets for sweet potatoes. *Implications from the study suggest that the procedure is potentially of great value to shippers if properly understood and applied.* The procedure may be additionally refined and improved, and its application modified in time, with further use and study.

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Interregional Competition in Marketing Fresh Sweet Potatoes

By JERRY M. LAW AND HOMER G. PONDER

INTRODUCTION

Sweet potatoes are grown commercially in at least 23 states of the United States. Production is confined largely to the southern half of the country, with the more important areas of commercial output located in Louisiana, New Jersey, Virginia, North Carolina, Texas, and California.[1]

Striking changes have taken place within the United States sweet potato industry over the past two to three decades. Despite a greatly expanded consumer population, annual consumption of sweet potatoes in the country fell by more than one-third since the middle 1930's. Annual consumption per person declined from 23 pounds, fresh equivalent, in 1934-37 to less than 7 pounds in 1960-63. In part, the decline in consumption reflects a decline in household use of the product on farms where grown.[2] However, the quantity of sweet potatoes moving into sales outlets has declined by almost 20 percent since the 1934-37 period.[3]

Acreage of sweet potatoes harvested annually dropped by approximately 74 percent between the periods 1934-37 and 1959-62. The drop in acreage was relatively consistent, except during World War II, when the trend was interrupted temporarily. Although yield per acre increased 60 percent over the period, annual production of sweet potatoes dropped steadily from over 39 million hundredweight during 1934-37 to less than 17 million hundredweight during 1959-62—a decline of approximately 57 percent. Much of the decline in output was in production for home use. However, changes in commercial production were significant.[4]

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[1] Other states growing significant quantities commercially include Alabama, Arizona, Georgia, Kansas, Maryland, Mississippi, Missouri, New Mexico, South Carolina, and Tennessee.

[2] Since the 1934-37 period the household use of sweet potatoes on farms where grown has declined from approximately 15 million to approximately 2 million hundredweight.

[3] Statistical information presented in this section was compiled from the following sources: (a) *Consumption of Food in the United States 1909-52,* Agricultural Handbook No. 62, U. S. Department of Agriculture, Washington, D. C., September 1953, and supplements for 1958, 1960, and 1962; (b) *National Food Situation,* Economic Research Service, U. S. Department of Agriculture, Washington, D. C., various issues since 1960; and (c) *Agricultural Statistics,* U. S. Department of Agriculture, Washington, D. C., various annual issues.

According to the Census of Agriculture, the number of farms reporting the production of sweet potatoes declined from approximately 1.2 million in 1939 to 310 thousand in 1959—a decrease of more than 74 percent. This change was accompanied by a trend toward larger acreage per farm as production of the crop became increasingly commercialized and specialized.

Shifts in Supply Areas

Changes in production of sweet potatoes are reflected in marked changes in relative output between regions and between states within regions. The Southern Region[5] supplied over 86 percent of the United States output during the 1934-37 period. By 1959-62 the proportion produced in this region had decreased to about 80 percent of the United States total. Over this period, however, total output within the region decreased by approximately 61 percent. And there were significant shifts in the relative importance of different supply areas within the region. Although output in all states of the region declined, the relative importance of production in Louisiana, North Carolina, Texas, and Virginia increased from 40 to 69 percent of the regional total. The relative importance of production in each of the other seven states declined sharply.

The Western Region, primarily California,[6] gained in production and increased its share from less than 2 percent to almost 6 percent of the United States output between 1934-37 and 1959-62.

Sweet potato output in the Northeastern Region[7] declined. Output increased slightly in New Jersey but declined slightly in Maryland and almost totally in Delaware. However, the relative importance of the Northeastern Region increased from about 6 percent to about 12 percent of the United States output.

Other states for which sweet potato production is reported include Indiana, Illinois, Iowa, Missouri, Kansas, Kentucky, and Oklahoma.

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[4] Statistical information on acreage, yield, and production in this section and subsequent sections of the report was compiled from the following sources: (a) *Potatoes and Sweetpotatoes,* Statistical Bulletin 190, Crop Reporting Board, Agricultural Marketing Service, U. S. Department of Agriculture, Washington, D. C., August 1956; (b) *Sweetpotatoes,* Statistical Bulletin No. 237, Crop Reporting Board, Agricultural Marketing Service, U.S. Department of Agriculture, Washington, D. C., September 1958; and (c) subsequent annual summaries of *Potatoes and Sweetpotatoes,* Statistical Reporting Service, U. S. Department of Agriculture, Washington, D. C.

[5] The Southern Region of the United States is defined to include the states of Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas, and Virginia.

[6] Only one other state in this region, New Mexico, produces sweet potatoes.

[7] Sweet potato producing states in this region include New Jersey, Delaware, and Maryland.

Since the 1930's the combined output of these states declined from over 6 percent to less than 3 percent of the United States total.

The Problem

Changes in the sweet potato industry have had a major impact on the competitive positions of sellers in different producing areas. Farmers, shippers, and others inevitably face the problem of adjusting to changes of this nature. The most profitable solution to this adjustment problem requires a complex of economic information on competing supplies, demand conditions, and transportation costs. Much of the information is not readily available to sellers. *Moreover, a procedure is lacking for making effective use of such information in determining needed adjustments.*

Purpose of the Study

This study was made to provide shippers with information needed to make decisions leading to the most profitable allocation of sweet potato supplies among major consuming centers. The specific objective of the study was to compare net receipts from the actual and from an optimum allocation of sweet potato supplies from each producing area to major consuming centers for a recent season.[8] In carrying out this objective it was intended that the study also serve to illustrate a procedure which may be used for guiding adjustments to future changes in the industry.

Although the study involves all producing areas, it is of greatest importance to the Southern Region, where almost 80 percent of the United States sweet potato output is produced. Louisiana, which supplies about one-fourth of the nation's output, is given particular emphasis in the study.

Markets and Supply Areas Studied

Unload data for the 1958-59 season indicated that sweet potatoes were shipped to at least 100 cities and towns throughout the United States. However, unloads at 26 major cities accounted for most of the sweet potatoes shipped.[9] Since price and quantity data were available for these cities all were included in the study. However, for purposes of analysis, Dallas and Fort Worth, Minneapolis and St. Paul, New York and Newark, and San Francisco and Oakland were considered as four consuming centers rather than eight. This reduced the number of consuming centers included in the study to 22 (see Figure 1).

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[8] Data for the 1958-59 shipping season were used for the study.

[9] The cities include Atlanta, Baltimore, Birmingham, Boston, Chicago, Cincinnati, Cleveland, Dallas, Denver, Detroit, Fort Worth, Kansas City, Los Angeles, Louisville, Minneapolis, New Orleans, Newark, New York, Oakland, Philadelphia, Pittsburgh, Portland, St. Louis, San Francisco, St. Paul, and Washington, D. C.

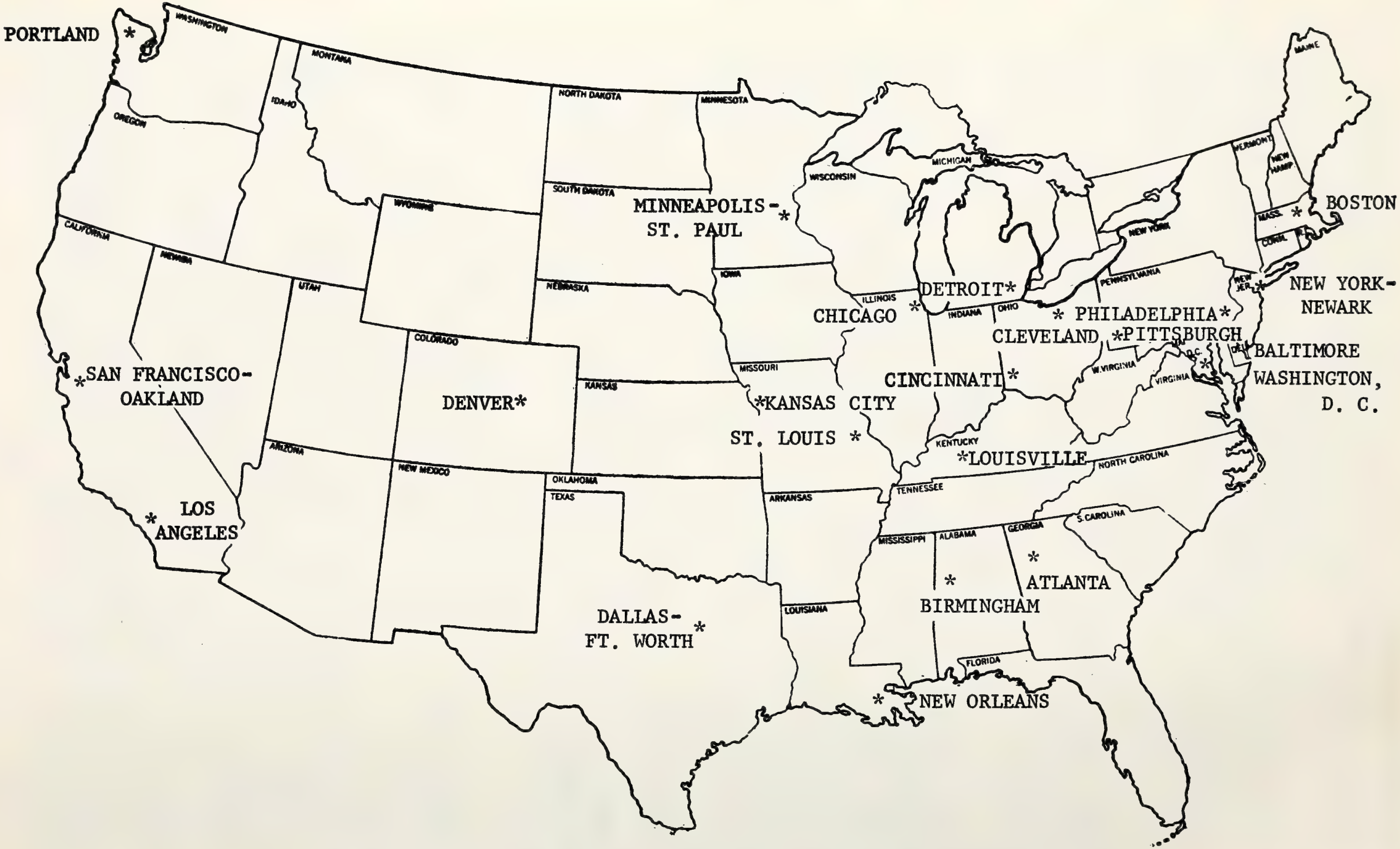

FIGURE 1.—Consuming Centers Selected for Study, 1958-59 Marketing Season.

Twenty-three states which supplied sweetpotatoes to the consuming centers above were included in the study. To facilitate analysis a single shipping point was selected for each of the 23 states (see Table 1). The selection was based upon areas of concentrated acreage and/or areas showing concentrated volumes of shipment.

TABLE 1.–Supply Areas and Shipping Points Selected for Study, 1958-59 Marketing Season

State	Shipping point	State	Shipping point
Alabama	Cullman	Louisiana	Opelousas
Arizona	Phoenix	Maryland	Salisbury
Arkansas	El Dorado	Mississippi	Vardaman
California	Atwater	Missouri	Manchester
Delaware	Salisbury, Md.	New Jersey	Vineland
Florida	Fort Pierce	New Mexico	Portales
Georgia	Americus	North Carolina	Benson
Illinois	Dongola	South Carolina	Kingstree
Indiana	Owensville	Tennessee	Dresden
Iowa	Muscatine	Texas	Tyler
Kansas	Manhattan	Virginia	Onley
Kentucky	Dresden, Tenn.		

Method of Analysis

This study involves an application of the theory of interregional competition to the problem of determining the optimum allocation of sweet potato supplies among major consuming centers. An optimum allocation was determined for each of four different situations as follows:

1. Optimum allocations of existing supplies from Louisiana with actual allocations from other producing areas.
2. Optimum allocations of increased supplies from Louisiana with actual allocations from other producing areas.
3. Optimum allocations of existing supplies from all producing areas.
4. Optimum allocations of increased supplies from Louisiana and existing supplies from other producing areas.

Analysis for each of the above situations involved the technique of reactive programming. Reactive programming is a means of obtaining equilibrium flows of a commodity between areas with given transportation cost functions, given demand schedules in each of several consuming centers, and given supply schedules in each of several areas of production.[10] The model for the study consists of the following components:

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[10] For a detailed explanation of the reactive programming technique, see: Tramel, Thomas E., and A. D. Seale, Jr., "Reactive Programming of Supply and Demand Relations – Applications to Fresh Vegetables," *Journal of Farm Economics,* XLI, December 1959, pp. 1012-22.

1. *Demand schedules for each consuming center.* The development of the statistical model used in estimating demand functions for major consuming centers is presented in Appendix A. The equations take the form of:

$$P_j = F_j \left(\sum_{i=1}^{m} Q_{ij}\right), \text{ where}$$

$i = 1, 2, \ldots, m$ denotes the different producing areas,

$j = 1, 2, \ldots, n$ denotes the different consuming centers,

P_j denotes price of the homogeneous product in the j*th* consuming center,

Q_{ij} denotes the quantity purchased in the j*th* consuming center which was produced in the i*th* producing area.

2. *The transportation cost from each producing area to each consuming center.* The development of the statistical model used in estimating transportation costs is presented in Appendix B. These costs take the form of:

An m x n matrix of T_{ij}'s where T_{ij} denotes constant unit cost of transporting the product from the i*th* producing area to the j*th* consuming center.

3. *The supply available in each producing area.* This is symbolized as:

A vector of m x s_i's where S_i denotes the fixed supply in the i*th* producing area.

From the given data, m x n equations may be formed of the following:

$R_{ij} = F_j(\Sigma Q_{ij}) - T_{ij}$, $i = 1, 2, \ldots, m$; $j = 1, 2, \ldots, n$, where R_{ij} denotes the "net" average revenue per unit for the product produced in the i*th* producing area and sold in the j*th* consuming center. Each of the m x n equations defines, for each producing area, the net price which can be obtained in each consuming center. A solution to the m x n equations is a solution to the optimum allocation of supplies among markets. The solutions were obtained on the IBM 650 computer.

Four restrictions imposed on the model are as follows:

1. All $Q_{ij} \geqq 0$, i.e., the quantities purchased in a consuming center from a producing area must be equal to or greater than zero.

2. For a given i, all R_{ij}'s must be equal for all j's to which shipments are made and in turn must be greater than all R_{ij}'s for all j's to which shipments are not made. Simply stated, a producing area must receive the same net revenue per unit from all consuming centers it supplies, and this revenue must be greater than the revenue obtainable at other consuming centers.

3. $R_{ij} \geqq 0$ for all i's and all j's between which the commodity

flows. In other words, for a commodity to flow from a given producing area to a given consuming center the net revenue must be equal to or greater than zero.

4. $\sum_{j=1}^{n} Q_{ij} \leqq S_i$ This means that the quantity purchased in a consuming center from a given producing area must not exceed the supply available in that producing area.

Sources of Data

Input data used in the study were obtained from several sources. Data on unloads by origin and wholesale prices in each consuming center were obtained from daily and summary market news reports.[11] Population and income data used in the analysis of demand for each consuming center were obtained from *Sales-Management Survey of Buying Power.*[12]

Data needed to estimate transportation costs were obtained by personal interview with truck brokers and shippers operating in the Louisiana sweet potato area. Direct mileages between producing areas and consuming centers were compiled from highway mileage charts in a road atlas.[13]

Demand, supply, and transportation cost coefficients[14] developed from the above information constituted the input data for the reactive programming technique.

Limitations

Certain limitations are inherent in most studies. The more important ones in this study emerge as a result of necessary simplifying assumptions, the nature of input data, and barriers existing in the distribution channels that may prevent optimum allocations.

In this study sweet potatoes were considered a homogeneous product in that those produced in one section of the United States were perfect substitutes for those grown in other sections. Two types of sweet potatoes are produced in the United States, the moist type as found in Louisiana, and the dry type as found in the Northeastern Region. Generally, the moist type commands a price premium and is preferred to the dry type in some consuming centers. Lack of data, however, prevented an analysis based on preference of the product from a given production area by any or all consuming centers.

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[11] These reports are published periodically by the Federal-State Market News Service.

[12] "Summary of Data for Metropolitan County Areas," *Sales-Management Survey of Buying Power,* New York: Bill Brothers Publishing Corporation, May 10, 1959.

[13] *Road Atlas.* Chicago: Rand McNally and Company, 1958.

[14] Demand coefficients and transportation cost coefficients are presented in Appendix B and Appendix C, respectively.

Each source of supply is represented by a single point. This is one of the mechanical requirements used in the technique and may cause minor differences in actual aggregate transportation costs. It was assumed that per unit transportation cost was the same for all producing areas. Transportation costs are also computed on constant unit cost throughout the entire season. Discounts and premiums may be used to adjust these rates for changes in supply and demand for trucking services. Transportation rates, however, appear to be highly uniform among different firms.

An optimum allocation of sweet potatoes from each producing area may be difficult to achieve in practice. The distribution pattern may be altered by such things as imperfections in the marketing system and subjective factors influencing sales. Shippers as well as buyers may wish to maintain contact with well-established, reputable suppliers or receivers. Any short-run gain accruing to a shipper from an optimum distribution may be offset by personal values or long-run benefits derived from maintaining market contacts. Encroachment on a market by competitors could easily result in retaliatory measures, such as price cutting, which would alter an otherwise optimum allocation. Inadequate knowledge and trade barriers also may prevent optimum distributions.

It should be noted that the allocations of sweet potatoes developed in the analysis represented only part of the total sold. Consumption data for some markets were unattainable and in others may have been incomplete. The study does include a majority of the fresh sweet potatoes marketed during the year, however, and should serve as a basis for developing long-range plans on the part of producers and shippers.

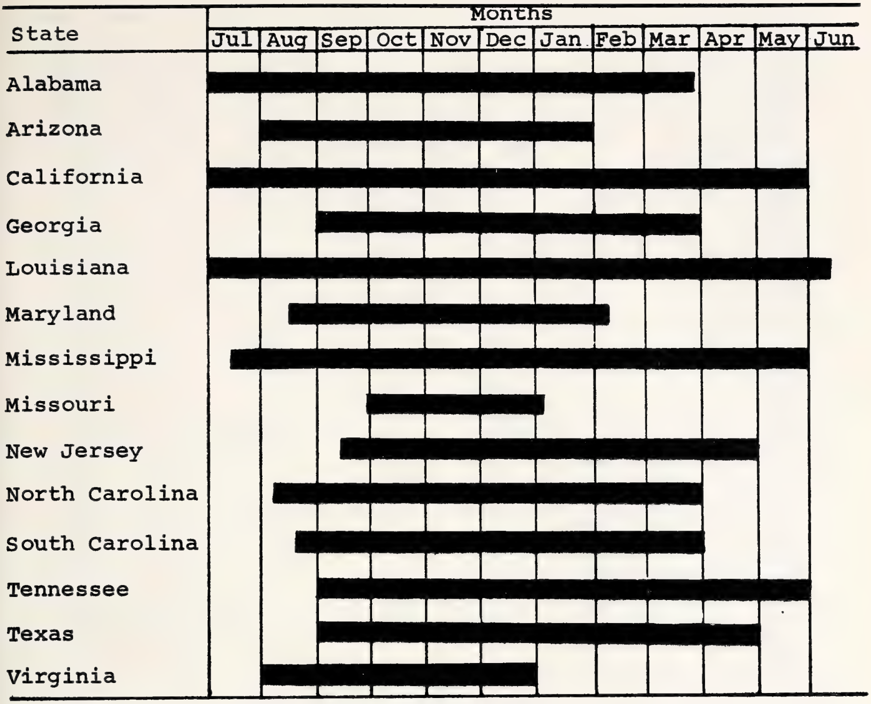
SHIPPING PATTERNS FOR COMPETING STATES

Actual shipments of sweet potatoes to major consuming centers during the 1958-59 marketing season served as a basis from which needed adjustments in shipping patterns were estimated. A description of the shipping periods and patterns for the 1958-59 season is presented in this section.

Shipping Periods

The shipping season in each producing area begins at time of harvest. Early shipments consist of "uncured" or "green" sweet potatoes. As harvest progresses, an increasing proportion of the crop moves into storage. Soon after harvest is completed, all subsequent shipments for the season are made from "cured" stocks. With proper storage facilities it is possible to extend the shipping season to a year-round basis.

Usual shipping seasons for the principal commercial areas are shown in Figure 2. The earliest seasons generally begin in July with limited



Source: *The Packer Fresh Fruit and Vegetable Yearbook—1957 Issue,* Part Two, Kansas City: The Packer Publishing Co., April 1957, p. 190.

FIGURE 2.—Usual Shipping Seasons for Principal Sweet Potato States.

shipments from Louisiana, Alabama, and California. Most of the states have begun shipments by early September. The end of the shipping season for many areas occurs between January and April. Louisiana has the longest season, with shipments extending between 11 and 12 months.

Allocation of Shipments Among Consuming Centers

From Louisiana. Louisiana shippers supplied 3,447 of the 14,174 carlot equivalents of sweet potatoes unloaded at 22 major markets during the 1958-59 shipping season (Table 2). Chicago was by far the most important market for Louisiana sweet potatoes. Shipments to this consuming center amounted to 1,080 carlot equivalents, or 31 percent of all shipments from the state. Other leading markets included Detroit, New Orleans, Cleveland, St. Louis, Cincinnati, Pittsburgh, and Kansas City. Louisiana shippers allocated considerably more than 100 carlot equivalents to each of these cities. With the exception of Cincinnati and Pittsburgh, Louisiana supplied most of the sweet potatoes consumed in the cities named above, accounting for 100 percent in New Orleans, 88.5 percent in Chicago, and 77.3 percent in Cleveland (Table 3).

TABLE 2.—Total Unloads of Sweet Potatoes in Specified Consuming Centers, by States of Origin, 1958-59 Marketing Season

Consuming center	Producing area											
	La.	N. J.	Cal.	N. C.	Va.	Tex.	Ala.	Md.	Ga.	Miss.	Ariz.	Mo.
	Carlot equivalents											
Atlanta	2	17		52	90	63	25	2	445	30		
Baltimore	25	223		20	160			235				
Birmingham	3					54	689		1	23		
Boston	3	350		6	38		1	46				
Chicago	1,080	30		3		75				11		
Cincinnati	163	6		26	11	35	3	26		9	39	
Cleveland	392	48		3	7	7		40		7		
Dallas-Ft. Worth						456						
Denver	87		13			67				5	44	
Detroit	485	2		50	2	2		1		3		
Kansas City	130					16				3	8	
Los Angeles			1,621								7	
Louisville	88			2			7	1		10		
Minneapolis-St. Paul	73	19				11				3		
New Orleans	442											
New York-Newark	78	837		740	392			171				
Philadelphia	21	735		163	255	1		86				
Pittsburgh	150	285		10	53	6		55		1		
Portland	1		141			16					6	
St. Louis	248		2	3		5		5		29		92
San Francisco-Oakland			588								7	
Washington, D. C.	6	84		172	55			37				
Total	3,477	2,636	2,365	1,250	1,063	814	725	705	446	134	111	92

(Continued)

TABLE 2.—(Continued)

Consuming center	Producing area											
	Tenn.	S. C.	Kan.	N. M.	Ark.	Ind.	Io.	Del.	Fla.	Ill.	Ky.	Pa.
						Carlot equivalents						
Atlanta	31	48						1				
Baltimore		7						2				
Birmingham									3			
Boston												
Chicago	16		4				1		1			
Cincinnati	17	1				7					1	
Cleveland						2			1			
Dallas-Ft. Worth				48								
Denver			1	4	8							
Detroit									1			
Kansas City			63		4							
Los Angeles												
Louisville	13											
Minneapolis-St. Paul			4				8					
New Orleans												
New York-Newark		22						4				
Philadelphia		6										
Pittsburgh												
Portland												
St. Louis	14		1							5		
San Francisco-Oakland												
Washington, D. C.		6										1
Total	91	90	73	52	12	9	9	7	6	5	1	1

Source: U. S. Department of Agriculture, Agricultural Marketing Service, Fruit and Vegetable Division, *Daily Fruit and Vegetable Reports,* Major Market Centers, July 1, 1958, through June 30, 1959.

TABLE 3.—Total Receipts of Sweet Potatoes in Specified Consuming Centers and Proportion of Receipts in Each Market Supplied from Louisiana and Competing Areas, 1958-59 Marketing Season

Consuming center	Total carlot equivalents	Percentage supplied by	
		Louisiana	Other states
Atlanta	806	.2	99.8
Baltimore	672	3.7	96.3
Birmingham	773	.4	99.6
Boston	444	.7	99.3
Chicago	1,221	88.5	11.5
Cincinnati	344	47.4	52.6
Cleveland	507	77.3	22.7
Dallas-Ft. Worth	504		100.0
Denver	229	38.0	62.0
Detroit	546	88.8	11.2
Kansas City	224	58.0	42.0
Los Angeles	1,628		100.0
Louisville	121	72.7	27.3
Minneapolis-St. Paul	118	61.9	38.1
New Orleans	442	100.0	
New York-Newark	2,244	3.5	96.5
Philadelphia	1,267	1.7	98.3
Pittsburgh	560	26.8	73.2
Portland	164	.6	99.4
St. Louis	404	61.4	38.6
San Francisco-Oakland	595		100.0
Washington, D. C.	361	1.7	98.3
Total receipts	14,174	24.5	75.5

Source: Table 2.

Areas Competing With Louisiana. Louisiana's major competitors in selling sweet potatoes include New Jersey, California, North Carolina, Virginia, and Texas. These states supplied approximately 60 percent of the total unloads in 22 major markets during the 1958-59 season. New York City was the largest market for eastern shippers, including those in New Jersey, North Carolina, Virginia, and Maryland (see Table 2). Shippers in these states also were the primary suppliers of other northeastern markets.

California sweet potatoes moved primarily to markets within the state, although some shipments were made to relatively nearby markets such as Portland, Oregon. Dallas and Fort Worth were major receivers of Texas sweet potatoes. Shipments from Texas also were distributed to several north central and eastern cities. The bulk of supplies from other producing states was distributed primarily within the state of production.

OPTIMUM SHIPPING PATTERNS

As indicated earlier the optimum (i.e., most profitable) allocation of sweet potato supplies among major consuming centers was estimated for four different situations. Each situation will be presented in turn.

Situation 1. Optimum allocation of existing supplies from Louisiana with actual allocations from other producing areas

During the nine-month period August 1958 through April 1959, Louisiana shippers supplied 3,100 of the 12,765 carlot equivalents of sweet potatoes unloaded at 22 major markets.[15] The sale of 3,100 carlots netted Louisiana shippers an estimated $5,128,402 (gross receipts less transportation cost). Net revenue per carlot averaged $1,654.

Assuming no change in shipments from other producing areas, an optimum allocation of the 3,100 carlots of sweet potatoes from Louisiana would have increased net returns to shippers in the state by $567,913, or $184 per carlot. The most profitable distribution would have called for a greater proportion of Louisiana sweet potato shipments to West Coast markets where population is expanding rapidly. Increased shipments were indicated for Los Angeles, Portland, and San Francisco (Table 4). Additional shipments also were indicated for the Denver and Minneapolis-St. Paul markets. Increased shipments to the above consuming centers would have been offset by fewer shipments to others.

As explained earlier, the shipping season for Louisiana sweet potatoes is somewhat longer than that of most other producing areas. Thus, the competitive position of Louisiana shippers changes somewhat during the season. As a consequence of this, and possibly other factors, the optimum allocation of supplies shifts somewhat between certain periods of the maketing season. Optimum allocation for individual marketing periods within the season are presented in Appendix C, Tables 11, 12, and 13.

Situation 2. Optimum allocation of increased supplies from Louisiana with actual allocations from other producing areas

It seems reasonable to assume that Louisiana could increase supplies of sweet potatoes for the fresh market by 50 percent over the volume shipped from the state during the 1958-59 marketing season.[16] This would mean that the quantity of Louisiana sweet potatoes available for distribution would be increased to 4,648 carlot equivalents. An analysis was made to determine what effect an optimum allocation of this increased supply would have on net revenue to Louisiana shippers.

The analysis is based upon the assumption of no change in unloads from areas other than Louisiana. As might be expected, an increase of 50 percent in supplies from Louisiana would result in lower prices.

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[15] As indicated earlier, shipments from Louisiana for the entire season totaled 3,477 carlots. However, the relatively few shipments (377 carlots) made in July 1958 and after April 1959 were not included in the study because of insufficient data to support the analysis.

[16] This potential is estimated on the basis of the quantity of suitable land available, climatic requirements, alternative land uses, and prospects for increased yields with improved varieties.

TABLE 4.—Results of Actual and Optimum Allocations of Existing Supplies of Louisiana Sweet Potatoes in 22 Major Markets, with Actual Allocations From Competing Areas, 1958-59 Marketing Season

Consuming center	Unloads		
	Actual, from areas other than Louisiana	From Louisiana	
		Actual	Optimum
	Carlot equivalents		
Atlanta	723		
Baltimore	585	22	
Birmingham	693	2	
Boston	410	2	
Chicago	140	951	748
Cincinnati	167	137	66
Cleveland	114	348	300
Dallas-Ft. Worth	489	[a]	[a]
Denver	139	72	115
Detroit	60	439	376
Kansas City	86	115	98
Los Angeles	1,423		72
Louisville	24	83	38
Minneapolis-St. Paul	51	73	272
New Orleans		399	242
New York-Newark	1,930	77	
Philadelphia	1,134	22	
Pittsburgh	365	134	60
Portland	150		156
St. Louis	137	219	130
San Francisco-Oakland	533		427
Washington, D. C.	312	5	
Total	9,665	3,100	3,100
Net revenue to Louisiana shippers		$5,128,402	$5,696,315

[a] Louisiana sweet potatoes were restricted from the Dallas-Fort Worth market because of quarantine regulations against entry of this product from weevil infested areas.

However, the change in price would be less than proportionate to the change in quantity. Consequently, net revenue to Louisiana shippers would be increased with the larger supply. Specifically, an optimum distribution of the larger supply would have increased net revenue (gross receipts less transportation costs) to $7,722,183 (Table 5). This represents an increase of more than 35 percent over the revenue obtainable with an optimum distribution of actual supplies.

Markets supplied by Louisiana shippers would remain the same as under an optimum distribution before an increase in volume, with one exception. With the increased supplies the city of Washington, D.C., would be added as a new market (see Table 5). The volume supplied in the other markets would be increased but in varying proportions. Optimum allocations for individual marketing periods within the season are presented in Appendix C, Tables 14, 15, and 16.

TABLE 5.—Results of a 50 Percent Increase in Sweet Potato Unloads from Louisiana, With Actual Allocations from Competing Areas, 22 Major Markets, 1958-59 Marketing Season

Consuming center	Unloads		
	Actual, from areas other than Louisiana	Optimum allocation from Louisiana	
		Existing supplies	Increased supplies
		Carlot equivalents	
Atlanta	723		
Baltimore	585		
Birmingham	693		
Boston	410		
Chicago	140	748	922
Cincinnati	167	66	104
Cleveland	114	300	349
Dallas-Fort Worth	489	[a]	[a]
Denver	139	115	235
Detroit	60	376	476
Kansas City	86	98	144
Los Angeles	1,423	72	240
Louisville	24	38	88
Minneapolis-St. Paul	51	272	446
New Orleans		242	324
New York-Newark	1,930		
Philadelphia	1,134		
Pittsburgh	365	60	106
Portland	150	156	352
St. Louis	137	130	174
San Francisco-Oakland	533	427	654
Washington, D. C.	312		34
Total	9,665	3,100	4,648
Net revenue to Louisiana shippers		$5,696,315	$7,722,183

[a] Louisiana sweet potatoes were restricted from the Dallas-Fort Worth market because of quarantine regulations against entry of this product from weevil infested areas.

Situation 3. Optimum allocation of existing supplies from all producing areas

The preceding situations involved optimum shipping patterns for Louisiana with actual unloads from other producing areas. This section is concerned with optimum shipping patterns for *each producing area, assuming that all areas changed toward an optimum simultaneously*. At this point it seems appropriate to point out the possibility of results for a given producing area which, at first, may seem contradictory with an adjustment toward an optimum shipping pattern. That is, a given producing area may show less net revenue with an optimum shipping pattern than before. This is possible when the gain obtained by moving to an optimum pattern is more than offset by competitive forces generated by other areas simultaneously adjusting to an optimum pattern. Even though it would appear to result in lost revenue, the optimum shipping pattern would be the best that the area could achieve *when all areas shift to an optimum.* Under these circumstances any other shipping pattern would result in still less revenue for the producing area.

Shipments of sweet potatoes from all producing areas to 22 major consuming centers totaled 12,765 carlot equivalents for the period August 1958 through April 1959. The wholesale value of this quantity at the market totaled $23,968,343. Cost of transporting the 12,765 carlots from producing areas to consuming centers amounted to $2,176,900. Consequently, the net revenue to producing areas was $21,971,443 (Table 6).

If optimum shipping patterns had been followed, the resulting net revenue to the industry would have been $22,434,856 (Table 6). This represents an increase of 3 percent, or $643,413, over the net revenue derived from actual unloads. Optimum shipping patterns for the industry would have resulted in gains to some areas and losses to others. Changes in net revenue to individual producing areas would have ranged from an increase of $316,162 for New Jersey to a decrease of $520,835 for California (see Table 6). The major sweet potato pro-

TABLE 6.—Net Revenues to Producing Areas for Existing Supplies of Sweet Potatoes Under Actual and Optimum Shipping Patterns for the Industry, 1958-59 Marketing Season

Producing area	Shipping pattern		Net change from actual to optimum	
	Actual	Optimum		
	— — — —	*Dollars* — — —	— — —	*Percent*
Alabama	1,016,968	1,158,723	141,755	13.9
Arizona	196,064	216,769	20,705	10.6
Arkansas	16,756	15,912	- 844	- 5.0
California	4,747,363	4,226,528	–520,835	–11.0
Delaware	10,682	13,424	2,742	25.7
Florida	2,440	3,320	880	36.1
Georgia	684,860	714,204	29,344	4.3
Illinois	3,690	3,550	- 140	- 3.8
Indiana	13,776	14,034	258	1.9
Iowa	17,500	14,474	- 3,026	–17.3
Kansas	136,616	124,310	- 12,306	- 9.0
Kentucky	3,736	3,590	- 146	- 3.9
Louisiana	5,128,402	5,154,293	25,891	.5
Maryland	1,021,374	1,164,281	142,907	14.0
Mississippi	232,985	302,129	69,144	29.7
Missouri	148,307	158,540	10,233	6.9
New Jersey	3,532,884	3,849,046	316,162	8.9
New Mexico	79,153	92,112	12,959	16.4
North Carolina	1,664,131	1,770,607	106,476	6.4
South Carolina	135,699	147,964	12,265	9.0
Tennessee	97,303	102,552	5,249	5.4
Texas	1,277,659	1,340,086	62,427	4.9
Virginia	1,623,095	1,844,408	221,313	13.6
Total	21,791,443	22,434,856	643,413	3.0

ducing states, except California, would have benefited from optimum shipping patterns for the industry.

Changing from actual to optimum shipping patterns for all producing areas in 1958-59 would have called for increased volumes in some consuming centers and decreased volumes in others (Table 7). For some of the major consuming centers, such as Chicago and New York City, unloads would have remained approximately unchanged.

Changes in pattern of shipments and net prices per carlot for individual states are presented in Appendix C, Tables 26 through 71. Generally, producing areas would have supplied all or most of the volume to consuming centers located within the state. Any remaining supplies would have been shipped to out-of-state markets.

Shipments from Louisiana would have been altered somewhat under situation 3. With all areas moving to an optimum shipping pattern, the best markets for Louisiana sweet potatoes would have included Los Angeles, Chicago, Minneapolis-St. Paul, New Orleans, and St. Louis. Although Louisiana shipments would have been made to other destinations, the above named centers would have received most of the shipments originating in the state. A change to the optimum pattern

TABLE 7.—Unloads of Existing Supplies of Sweet Potatoes at 22 Consuming Centers Under Actual and Optimum Shipping Patterns for the Industry, 1958-59 Marketing Season

Consuming center	Shipping pattern	
	Actual	Optimum
	Unloads (carlot equivalents)	
Atlanta	723	689
Baltimore	607	
Birmingham	695	573
Boston	412	50
Chicago	1,091	1,080
Cincinnati	304	287
Cleveland	462	500
Dallas-Fort Worth	489	467
Denver	211	378
Detroit	499	590
Kansas City	201	232
Los Angeles	1,423	1,647
Louisville	107	123
Minneapolis-St. Paul	124	508
New Orleans	399	324
New York-Newark	2,007	1,864
Philadelphia	1,156	518
Pittsburgh	499	515
Portland	150	563
St. Louis	356	313
San Francisco-Oakland	533	1,314
Washington, D. C.	317	230
Total	12,765	12,765

would have involved a shift of Louisiana shipments from northeastern markets to western markets, particularly Los Angeles.

Consuming centers in the northeast would have been supplied from producing areas in the middle eastern section of the country. Maryland and Virginia would have allocated the bulk of their shipments to New York City. New Jersey also would have shipped a substantial quantity of sweet potatoes to New York City, but would have supplied all of the unloads in Philadelphia and Boston, and most of those in Pittsburgh. Washington, D.C., would have been supplied primarily by North Carolina and Virginia.

Consuming centers in the north central and midwestern sections of the country generally are not near any particular area of production. Under optimum shipping patterns these consuming centers would have been supplied from several producing areas. However, each individual consuming center would have been supplied primarily by shippers in one or two producing areas. Cincinnati and Louisville would have been supplied principally by North Carolina; Cleveland and Detroit by New

TABLE 8.—Effect of a 50 Percent Increase in Louisiana Sweet Potato Shipments on Net Revenue to Specified Producing Areas, With Optimum Shipping Patterns for the Industry, 1958-59 Marketing Season

Producing area	Net revenue: With existing supplies	Net revenue: With increased supplies from Louisiana	Change in net revenue when Louisiana supplies are increased
		Dollars	
Alabama	1,158,723	1,111,013	-47,710
Arizona	216,769	204,625	-12,144
Arkansas	15,912	15,045	-867
California	4,226,528	4,039,784	-186,744
Delaware	13,424	12,930	-494
Florida	3,320	3,114	-206
Georgia	714,204	683,826	-30,378
Illinois	3,550	3,310	-240
Indiana	14,034	13,260	-774
Iowa	14,474	13,682	-792
Kansas	124,310	117,320	-6,990
Kentucky	3,590	3,314	-276
Louisiana	5,154,293	7,245,689	2,091,396
Maryland	1,164,281	1,122,332	-41,949
Mississippi	302,129	293,285	-8,844
Missouri	158,540	149,330	-9,210
New Jersey	3,849,046	3,700,372	-148,674
New Mexico	92,112	87,144	-4,968
North Carolina	1,770,607	1,703,449	-67,158
South Carolina	147,964	140,966	-6,998
Tennessee	102,552	96,698	-5,854
Texas	1,340,086	1,264,372	-75,714
Virginia	1,844,408	1,788,798	-55,610
Total	22,434,856	23,813,658	1,378,802

Jersey; and Chicago, Minneapolis-St. Paul, St. Louis, and Kansas City by Louisiana.

Western consuming centers would have been supplied primarily by California, Texas, and Louisiana. However, all of Mississippi's out-of-state shipments would have been sent to Portland, and all of the shipments from New Mexico and Arizona would have gone to Los Angeles. California would have been the principal supplier in Portland and the only supplier in San Francisco-Oakland. Denver would have been supplied mainly from Texas and Louisiana, and Los Angeles by Louisiana, Texas, and California.

Situation 4. Optimum allocations of increased supplies from Louisiana and existing supplies from other producing areas

This situation was based upon the assumption that sweet potato shipments from Louisiana were 50 percent larger than the volume

TABLE 9.—Effect of a 50 Percent Increase in Louisiana Sweet Potato Shipments on Optimum Shipping Patterns for the Industry, 1958-59 Marketing Season

Consuming center	Optimum unloads from areas other than Louisiana		Optimum unloads from Louisiana	
	Before increase in Louisiana shipments	After increase in Louisiana shipments	Before increase in Louisiana shipments	After increase in Louisiana shipments
	Carlot equivalents			
Atlanta	689	713		14
Baltimore				
Birmingham	565	454	8	160
Boston	50	176		
Chicago	360	81	720	1,103
Cincinnati	271	257	16	50
Cleveland	500	510		2
Dallas-Fort Worth	467	515	[a]	[a]
Denver	207	230	171	287
Detroit	590	548		80
Kansas City	68	18	164	243
Los Angeles	646	516	1,001	1,276
Louisville	107	55	16	88
Minneapolis-St. Paul	14	38	494	572
New Orleans			324	368
New York-Newark	1,864	1,990		
Philadelphia	518	642		
Pittsburgh	515	533		
Portland	563	577		84
St. Louis	127	41	186	301
San Francisco	1,314	1,412		20
Washington, D. C.	230	359		
Total	9,665	9,665	3,100	4,648

[a] Louisiana sweet potatoes were restricted from the Dallas-Fort Worth market because of quarantine regulations against entry of this product from weevil infested areas.

shipped from the state during the period August 1958 through April 1959. The analysis was concerned with optimum shipping patterns for the industry, with the increased supplies from Louisiana and the actual supplies from other producing areas. With the increased supplies from Louisiana, unloads from all areas would have totaled 14,313 carlot equivalents for the period specified. Optimum distribution of this volume would have increased net revenue to the industry by 6.1 percent, or $1,378,802 (Table 8). The increase in supplies would have resulted in lower prices in each market and thus lower net revenue for all states except Louisiana. Obviously, Louisiana shippers would have benefited considerably from the increased supplies under this situation. Although there would have been a reduction in price per carlot, net revenue to Louisiana shippers would have increased to $7,245,689.[17] This would have represented an increase of more than 40 percent over the net revenue from an optimum allocation of actual supplies (see Table 8).

An increase in shipments from Louisiana would have increased the volume of unloads in consuming centers. The new optimum would have called for Louisiana shipments to five additional cities (Table 9). However, increased shipments from Louisiana would not have altered appreciably the optimum shipping patterns for most of the other producing states.

SUMMARY AND CONCLUSIONS

Changes in the sweet potato industry have had a major impact on the competitive positions of sellers in different producing areas. Farmers, shippers, and others inevitably face the problem of adjusting to changes of this nature. The most profitable solution to this adjustment problem requires a complex of economic information, much of which is not readily available to sellers. *Moreover, a procedure is lacking for making effective use of such information in determining needed adjustments.*

The purpose of this study was to provide sweet potato shippers with information needed to achieve the most profitable allocation of supplies among major consuming centers. The specific objective was to indicate needed adjustments in shipping patterns by comparing net receipts from the actual and from an optimum allocation of sweet potatoes from each producing area to major consuming centers for a recent period. In carrying out this objective it was intended that the study also serve to illustrate a procedure which may be used for guiding adjustments to future changes in the industry. Primary emphasis is placed upon the

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[17] It should be emphasized that net revenue for the present study means gross revenue less transportation costs only. Lower prices resulting from increased supplies from Louisiana were not considered in relation to production and packing shed costs, for example.

Louisiana industry; however, information is provided for all commercial producing areas.

The 1958-59 marketing season was selected as the period for study. Basic information used in the analysis included estimates of (1) demand functions in major consuming centers, (2) sweet potato supplies in commercial producing areas, and (3) costs of transporting supplies from each producing area to all consuming centers. This information was analyzed by means of the reactive programming technique to determine the most profitable shipping patterns.

Louisiana's sweet potato shipments to selected markets during August 1958 through April 1959 resulted in a net revenue (gross receipts less transportation costs) of $5,128,402. An optimum allocation of Louisiana shipments among major consuming centers, with *existing allocations* from other producing areas, would have increased the state's net revenue by $567,913, or $184 per carlot.

Sweet potato shipments from all states during the 1958-59 season resulted in a net revenue of $21,791,443. An optimum allocation of supplies from all states would have increased net revenue to the industry by $643,413. The change would have affected individual states differently. Changes in net revenue would have ranged from an increase of $316,162 for New Jersey to a decrease of $520,835 for California. Louisiana's net revenue under this situation would have increased by $25,891.

An optimum allocation of 50 percent larger shipments of sweet potatoes from Louisiana, with existing allocations from other producing areas, would have yielded the state a net revenue of $7,722,183. This represents an increase of more than 35 percent over the revenue obtainable with an optimum allocation of actual supplies.

An optimum allocation of shipments from all states, with a 50 percent increase in Louisiana supplies, would have increased net revenue to the industry by 6.1 percent over the optimum allocation of existing supplies. The increase in supply would have resulted in lower prices in each market, and thus lower net revenue for all states except Louisiana. Net revenue to Louisiana shippers would have increased to $7,245,689.

Best markets for Louisiana sweet potatoes during the 1958-59 marketing season would have been similar with each supply situation studied but would have varied according to time periods within the season. Best shipping patterns would have involved more consuming centers during midseason than at the beginning or end.

Under optimum shipping patterns Louisiana would have maintained shipments to central and midwestern markets. However, some supplies would have been shifted from eastern to western markets. Best markets for Louisiana sweet potatoes would have been Los Angeles, Chicago, Minneapolis-St. Paul, New Orleans, and St. Louis. Other markets of importance to Louisiana shippers would have included Denver, Kansas City, Birmingham, Portland, Cincinnati, and Cleveland.

In general, with optimum shipping patterns for the industry, northeastern markets would have been supplied principally by middle eastern producing areas, southern markets by their respective states, north central and midwestern markets by several areas, but primarily by Louisiana, and western markets by California, Texas, and Louisiana.

The results of this study provide sweet potato growers and shippers with an indication of currently needed adjustments in the industry. It should be remembered that the results were obtained under the assumption of perfect competition and for marketing conditions existing during the 1958-59 shipping season. Significant departures from perfect competition, or changes in marketing conditions (demand, transportation rates, etc.) may call for somewhat different results. For instance, product differentiation could change the optimum distribution pattern.

If the Louisiana industry is successful in differentiating its sweet potatoes from those of other states, this would mean some degree of freedom from competition in selling. Any price premiums resulting from product differentiation would tend to offset any transfer cost disadvantages. For example, if buyers in New York City have a preference for Louisiana sweet potatoes and the preference is such that Louisiana shippers could command a price premium, they might compete successfully with middle eastern producing areas in supplying this market. Otherwise, their competitive position in this market is relatively unfavorable.

The study provides a procedure for guiding adjustments to future changes in the industry. The basic information utilized in determining the most profitable allocation of supplies for the 1958-59 season may be expected to change. Relative changes in demand conditions, transportation costs, and competing supplies would affect the optimum shipping pattern for Louisiana supplies. *However, this would not alter the usefulness of the model for guiding adjustments to these changes in the future. Estimates of change can be made on a current basis. With such estimates the most profitable allocation of sweet potatoes could be computed rapidly on high speed computers. Thus, shippers could be provided with these guides on a current and continuing basis.*

Louisiana holds a favorable competitive position in selling sweet potatoes. Shippers of the state stood to gain under all situations examined in the study. However, if they are to maintain or improve this competitive position they must keep abreast of changes in the industry and make adjustments accordingly.

APPENDIX A

DEMAND FOR SWEET POTATOES

Both the aggregate market approach and the individual market approach were considered for an analysis of the demand for sweet potatoes. The aggregate approach would yield a single demand function for all markets. This approach, however, failed to yield a logical demand function. Because of geographic differences in consumer reaction to sweet potatoes, it seemed necessary to make a separate analysis for each consuming area.

The Statistical Model

Single equation demand functions were estimated for seven of the major markets which were considered representative of the different geographical marketing areas of the United States. These markets included Chicago, New York City, St. Louis, New Orleans, Cleveland, Detroit, and San Francisco. Demand estimates for these markets were applied to surrounding markets but were adjusted to the market on the basis of the price, quantity, and income situation in the respective city.

The multiple regression technique was used in estimating the demand functions. This least squares approach is useful in showing what normal average relationships exist between sets of variables.

Several variables that appeared to be consistent with theory were tried in the first analysis. Variables maintained in the final analysis were either accepted or rejected on the basis of statistical significance and intuitive judgement. If high correlation existed between two independent variables, one of the variables was eliminated from the regression. The presence of intercorrelation not only reduced the statistical significance of the demand coefficients but also affected the size of the coefficients.

Data for the analysis were compiled on a monthly basis for the years 1954 through 1959. Monthly observations appeared to be feasible in light of the nature of the product. Preliminary graphic analysis of price-quantity data for each market depicted differences in seasonal demand. Distinct levels of demand were noted, with each level appearing to have similar slope. The price-quantity observations tended to group together in three distinct levels for most of the markets. One level consisted of observations for six months of the marketing season—September, October, January, February, March, and April. Another level was indicated by observations for November and December. A third level consisted of August observations. The remaining three months—May, June, and July—were eliminated from this analysis. Accurate relationships for these three months could not be established because of

APPENDIX TABLE 1.—Sweet Potato Carlot Unloads and Wholesale Price Per Carlot Equivalent in Specified Consuming Centers, by Months, Crop Years 1954-59

Year	Aug.		Sept.		Oct.		Nov.		Dec.		Jan.		Feb.		Mar.		Apr.	
	U[1]	P[2]	U	P	U	P	U	P	U	P	U	P	U	P	U	P	U	P
								CHICAGO										
1954*	63	1,485	115	1,625	134	1,735	240	1,950	190	2,475								
1955	49	1,510	106	1,435	146	1,340	250	1,555	188	1,675	127	2,450	109	2,525	103	2,540	101	2,540
1956	57	1,635	98	1,805	150	1,625	221	1,915	199	2,125	134	1,610	129	1,600	145	1,560	90	1,500
1957	52	1,865	97	1,860	150	1,870	229	2,115	171	2,455	113	2,175	113	2,150	104	2,200	114	2,480
1958	45	2,235	83	1,620	141	1,640	223	1,835	180	2,270	118	2,800	91	2,800	105	2,750	89	2,750
1959	39	1,665	95	1,525	149	1,440	238	1,500	175	1,855	97	2,020	97	1,820	142	1,835	82	1,820
								NEW ORLEANS										
1955*	16	1,500	29	1,360	56	1,310	69	1,310	65	1,340								
1956	19	1,725	31	1,660	60	1,560	137	1,575	99	1,830	75	1,440	61	1,375	51	1,375	37	1,330
1957	15	1,735	25	1,545	50	1,640	61	1,785	42	2,235	62	1,940	43	1,940	39	1,940	28	2,300
1958	13	2,015	28	1,400	58	1,375	52	1,560	70	1,835	39	2,375	35	2,375	31	2,375	26	2,310
1959	13	1,560	52	1,375	54	1,375	64	1,405	51	1,560	58	1,715	49	1,625	54	1,640	44	1,530
1960*											56	1,500	46	1,500	55	1,350	24	1,560
								LOS ANGELES										
1954	89	2,500	123	2,090	156	1,835	232	1,750	101	1,750	109	2,690	91	2,750	94	2,750	84	2,810
1955*	63		119		173		248		214		145		129		129		95	
1956	70	3,750	124	2,500	189	2,250	272	2,125	237	2,250	141	2,165	134	2,310	122	2,415	88	2,460
1957	55	3,250	130	2,500	173	2,310	276	2,000	254	2,125	132	2,500	129	2,500	122	2,500	137	2,750
1958	85	2,500	143	2,375	173	2,125	273	2,125	229	2,250	155	2,310	152	2,560	145	2,750	104	3,250
1959	99	2,500	151	2,375	180	2,060	265	2,000	191	2,125	127	2,375	130	2,310	165	2,310	91	2,250
								CLEVELAND										
1954*	35	1,655	51	1,690	63	1,850	72	2,060	64	2,580	43		43		47		43	
1955	28	1,625	58	1,625	60	1,440	85	1,675	65	1,875	45	2,650	43	2,690	43	2,690	43	2,690
1956	26	1,840	46	1,805	66	1,790	81	1,980	66	2,330	45	1,810	49	1,810	59	1,780	45	1,690
1957	27	2,030	56	1,965	66	1,950	80	2,280	70	2,900	58	2,340	48	2,340	48	2,310	50	2,630
1958	18	2,375	61	1,790	64	1,720	76	1,955	72	2,370	41	2,900	33	2,810	39	2,810	29	2,810
1959	24	1,715	58	1,560	56	1,485	80	1,630	62	2,030	35	2,210	43	2,055	50	1,985	40	1,940

(Continued)

APPENDIX TABLE 1.–(Continued)

Year	Aug.		Sept.		Oct.		Nov.		Dec.		Jan.		Feb.		Mar.		Apr.	
	U	P	U	P	U	P	U	P	U	P	U	P	U	P	U	P	U	P
								NEW YORK										
1954	109	2,365	241	1,170	280	1,400	435	1,425	306	1,570	202	1,695	201	1,660	232	1,615	196	1,835
1955	109	1,640	203	1,130	233	1,300	383	1,445	287	1,520	172	1,825	185	2,080	192	2,070	165	1,895
1956	93	2,050	168	1,280	264	1,430	359	1,515	281	1,575	214	1,535	193	1,520	204	1,365	186	1,305
1957	117	1,860	210	1,315	294	1,445	385	1,575	295	1,865	202	1,800	191	1,935	191	1,950	204	2,090
1958	77	1,910	219	1,460	289	1,340	366	1,785	312	1,980	194	2,235	164	2,405	185	2,510	160	2,520
1959	95	1,540	190	1,575	262	1,365	431	1,425	316	1,405	181	1,965	185	1,955	203	1,865	181	1,775
								DETROIT										
1954*	33	1,500	50	1,690	75	1,810	93	2,000	88	2,560								
1955	27	1,625	55	1,500	108	1,500	127	1,625	95	1,750	63	2,625	58	2,625	54	2,690	39	2,690
1956	29	1,875	62	1,875	89	1,750	111	2,000	86	2,375	78	1,750	85	1,790	81	1,790	62	1,690
1957	20	1,940	62	1,900	67	2,000	79	2,250	58	2,750	74	2,350	59	2,300	61	2,250	70	2,625
1958	21	2,390	53	1,795	61	1,795	92	1,975	67	2,370	46	2,875	42	2,875	51	2,940	37	2,875
1959	17	1,625	56	1,625	74	1,560	93	1,600	80	1,940	54	2,235	39	2,190	74	2,055	34	2,000
								ST. LOUIS										
1954*	38	1,455	50	1,570	64	1,680	74	1,905	64	2,410	56		47		44		30	
1955	25	1,560	48	1,375	65	1,350	66	1,490	59	1,700	48	2,440	46	2,560	38	2,560	27	2,560
1956	26	1,590	50	1,710	54	1,645	73	1,860	69	2,125	44	1,560	49	1,560	48	1,550	34	1,560
1957	22	1,810	53	1,810	52	1,810	70	2,015	51	2,530	49	2,270	43	2,250	39	2,250	39	2,530
1958	22	2,210	46	1,620	50	1,640	57	1,835	54	2,270	33	2,795	32	2,780	33	2,700	27	2,740
1959	23	1,695	45	1,455	40	1,440	65	1,500	47	1,820	33	2,015	35	1,820	39	1,835	30	1,810

[1]U = Carlot unloads.

[2]P = Price per carlot.

*Data not available for certain months.

Source: Unloads were obtained from "Carlot Unloads of Certain Fruits and Vegetables in 100 U.S. and 5 Canadian Cities," also "Truck Unloads in 39 U.S. and 5 Canadian Cities," U.S.D.A., A.M.S., Fruit and Vegetable Division, 1954 through 1960. Wholesale prices were obtained from various sources including, "Marketing Louisiana Sweet Potatoes," State Market News Service, La. Dept. of Agriculture, Crop Seasons 1954-59; "Fresh Fruit and Vegetable Prices," U.S.D.A., A.M.S., Fruit and Vegetable Division, 1954 through 1959, and "Los Angeles Wholesale Market Prices, Fruits and Vegetables," U.S.D.A. and California Dept. of Agriculture, 1954 through 1959.

the limited shipments during this period. For ease of discussion, the August period, the six-month period, and the two-month period will be referred to as marketing periods 1, 2, and 3, respectively.

Although demand was greatest in marketing period 3 and least during marketing period 1, the price-quantity slopes for all three periods were similar. With this situation a seasonal code variable was incorporated into the analysis to permit the aggregation of the seasonal demand equations into a single equation per market.

The data were subjected to both linear and non-linear techniques to determine which analysis would yield the best fit. Transformation of the data into logarithms and squares did not increase the closeness of fit. Therefore, the statistical model takes the linear form of:

$$(1)\quad Y_i = a + b_1X_{1i} + b_2X_{2i} + b_3X_{3i} + b_4X_{4i}$$

In this equation Y_i is wholesale price in dollars per carlot equivalent in consuming center i,[1] a denotes the Y intercept, X_{1i} is quantity in carlot unloads in consuming center i,[1] X_{2i} is per capita disposable income,[2] X_{3i} and X_{4i} are seasonal code variables for consuming center i, and b_1, b_2, b_3, and b_4 are the respective regression coefficients.

Empirical Demand Functions

Individual Markets

The demand functions for individual consuming centers are derived from the estimating equation developed in the preceding section. Appendix Table 3 shows the estimated regression coefficients, their

APPENDIX TABLE 2.—Metropolitan Per Capita Disposable Income for Specified Consuming Centers, 1954-59

Consuming center	1954	1955	1956	1957	1958	1959
			Dollars			
Atlanta	1,736	1,747	1,867	1,832	1,769	1,898
Baltimore	1,526	1,593	1,669	1,825	1,823	1,893
Birmingham	1,431	1,452	1,578	1,624	1,599	1,706
Boston	1,744	1,830	1,943	1,987	2,088	2,213
Chicago	2,090	2,175	2,305	2,315	2,279	2,473
Cincinnati	1,797	1,852	1,919	1,931	1,890	2,003
Cleveland	2,112	2,225	2,310	2,280	2,208	2,321
Dallas	1,976	1,901	1,990	1,957	1,897	1,884
Denver	1,754	1,721	1,796	1,899	1,957	2,080
Detroit	1,949	2,099	2,095	2,107	2,008	2,175
Kansas City	1,875	1,936	2,012	2,030	2,040	2,188
Los Angeles	1,886	1,989	2,110	2,206	2,176	2,312
Louisville	1,665	1,654	1,710	1,729	1,644	1,745
Minneapolis	1,773	1,893	1,937	1,974	1,917	2,041
New Orleans	1,539	1,520	1,606	1,648	1,652	1,732
New York City	1,975	2,050	2,135	2,288	2,283	2,402
Philadelphia	1,804	1,888	1,985	1,992	1,997	2,102
Pittsburgh	1,690	1,731	1,813	1,842	1,851	1,960
Portland	1,699	1,656	1,724	1,705	1,759	1,904
St. Louis	1,796	1,814	1,900	1,962	1,905	2,046
San Francisco	2,069	2,180	2,318	2,373	2,345	2,528
Washington, D. C.	2,156	2,208	2,265	2,304	2,212	2,361

Source: "Summary of Data for Metropolitan County Areas," *Sales-Management — Survey of Buying Power,* 1954-59.

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[1] See Appendix Table 1.

[2] See Appendix Table 2.

APPENDIX TABLE 3.—Estimated Values of Regression Coefficients for Demand Equations, for Specified Consuming Centers, 1954-59

Consuming center	a value	Unload		Disposable income		Season				Coefficient of correlation
						Marketing period 2		Marketing period 3		
		Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error	
Chicago	3,517.13345	– 7.76365**	2.53620	– .61156NS	.46904	759.14650**	236.28449	1,480.44450**	444.82204	.46673*
Cleveland	5,554.07600	–30.43288**	5.17260	–1.29281X	.71166	978.29945**	186.89490	1,678.00959**	287.81447	.69174**
Detroit	4,624.42075	–14.33089**	3.19694	–1.18112NS	.75016	850.90590**	197.03172	1,199.28640**	271.72470	.61297**
New York City	1,489.93640	– 3.90202**	1.08565	– .36295NS	.27370	233.46854NS	175.08846	657.44795*	306.10764	.53336**
St. Louis	5,560.61550	–30.05136**	6.07620	–1.62909*	.65384	791.54110**	189.7444	1,326.03715**	282.15780	.61588**
Los Angeles	2,731.37065	– 6.50210**	1.35329	.27530NS	.03074	366.01534X	192.45616			.70831**
New Orleans	1,085.47485	–17.14483**	3.36620	.56093NS	.06590	586.85455	132.71569			.67778**

X—Significant at the .10 level.
* Significant at the .05 level.
** Significant at the .01 level.
NS—Not significant at the .10 level.

significance, and corresponding standard errors for the 1954-59 period. The quantity coefficient established the slope of demand, but the level is adjusted to conditions existing in the 1958-59 marketing season.

The a is the constant term in the equation. It represents the price at which no sweet potatoes would be purchased. The b's represent the rate of change of the dependent variable per unit change in each independent variable when the other independent variables are held constant. Apparently, the unloads of sweet potatoes and per capita disposable income are negatively related to the wholesale price of sweet potatoes, whereas the seasons are positively related to price. With the exception of the income variable, these same relationships are true for all the markets. Disposable income is positively related to price in the New York, Los Angeles, and New Orleans consuming centers.

As expected, the analysis shows that the wholesale price for a given quantity of sweet potatoes is higher in marketing period 3 for some consuming centers. This period includes the Thanksgiving and Christmas holidays. A large number of consumers buy sweet potatoes as a special food for these holidays.

In order to estimate the price associated with varying quantities, the Y intercept for each consuming center must be adjusted by the relevant variables — income and season. This reduces the demand function to the following equation:

(2) $Y_i = A + b_1X_{1i}$,

where Y_i, b, and X_{1i} denote the same values as defined in equation (1). A is defined as: $A = a + b_2X_{2i} + b_3X_{3i} + b_4X_{4i}$ where the symbols denote the same as in equation (1). Estimates for the demand equations for individual consuming centers are computed for each marketing period for the 1958-59 season. (See Appendix Tables 4, 5, and 6.)

APPENDIX TABLE 4.—Coefficients for Demand Functions for Specified Consuming Centers, Marketing Period 1, 1958-59 Season

Consuming center	A value	Unload coefficient
Atlanta	3,312	–17.14483
Baltimore	1,971	– 3.90202
Birmingham	3,798	–17.14483
Boston	2,075	– 3.90202
Chicago	2,624	– 7.76365
Cincinnati	2,609	–30.43288
Cleveland	2,923	–30.43288
Dallas-Ft. Worth	3,307	–17.14483
Denver	3,607	– 6.50210
Detroit	2,691	–14.33089
Kansas City	2,616	–30.05736
Los Angeles	3,303	– 6.50210
Louisville	2,741	–30.05736
Minneapolis-St. Paul	2,412	– 7.76365
New Orleans	2,238	–17.14483
New York-Newark	2,210	– 3.90202
Philadelphia	2,157	– 3.90202
Pittsburgh	3,098	–30.43288
Portland	3,026	– 6.50210
St. Louis	2,747	–30.05736
San Francisco-Oakland	3,689	– 6.50210
Washington, D. C.	2,885	– 3.90202

APPENDIX TABLE 5.—Coefficients for Demand Functions for Specified Consuming Centers, Marketing Period 2, 1958-59 Season

Consuming center	A value	Unload coefficient
Atlanta	3,143	−17.14483
Baltimore	1,561	− 3.90202
Birmingham	2,935	−17.14483
Boston	1,793	− 3.90202
Chicago	2,684	− 7.76365
Cincinnati	2,713	−30.43288
Cleveland	3,436	−30.43288
Dallas-Ft. Worth	2,625	−17.14483
Denver	2,058	− 6.50210
Detroit	2,764	−14.33089
Kansas City	2,654	−30.05736
Los Angeles	3,236	− 6.50210
Louisville	2,195	−30.05736
Minneapolis-St. Paul	2,354	− 7.76365
New Orleans	2,319	−17.14483
New York-Newark	2,542	− 3.90202
Philadelphia	1,918	− 3.90202
Pittsburgh	3,463	−30.43288
Portland	2,645	− 6.50210
St. Louis	2,806	−30.05736
San Francisco-Oakland	3,016	− 6.50210
Washington, D. C.	1,734	− 3.90202

APPENDIX TABLE 6.—Coefficients for Demand Functions for Specified Consuming Centers, Marketing Period 3, 1958-59 Season

Consuming center	A value	Unload coefficient
Atlanta	3,244	−17.14483
Baltimore	1,719	− 3.90202
Birmingham	2,554	−17.14483
Boston	1,939	− 3.90202
Chicago	3,646	− 7.76365
Cincinnati	3,514	−30.43288
Cleveland	4,415	−30.43288
Dallas-Ft. Worth	2,882	−17.14483
Denver	2,416	− 6.50210
Detroit	3,319	−14.33089
Kansas City	2,979	−30.05736
Los Angeles	3,827	− 6.50210
Louisville	2,496	−30.05736
Minneapolis-St. Paul	2,706	− 7.76365
New Orleans	2,692	−17.14483
New York-Newark	3,201	− 3.90202
Philadelphia	2,274	− 3.90202
Pittsburgh	4,405	−30.43288
Portland	2,666	− 6.50210
St. Louis	3,538	−30.05736
San Francisco-Oakland	3,148	− 6.50210
Washington, D. C.	2,060	− 3.90202

Statistical Test for Combining Markets

As stated earlier, the aggregate market approach failed to yield a logical demand function. A further analysis was made to see if the demand functions computed for the individual markets could be combined into a single demand function appropriate for all markets.

Two statistical tests were made (Appendix Table 7). In one analysis a test was made to see if one regression of the usual form could be fitted to all observations. In making this test it was necessary to compute (1) the mean square of the difference in the sum of squares of deviations from regression of all observations and the sum of squares of pooled deviations for each market, and (2) the mean square of the pooled sum of squares. Calculation of an F value equal to 4.72 with 20 and 229 degrees of freedom (Test 1, Appendix Table 7) indicated that one regression of the usual form could not be fitted to all observations.

A second test was made to see if the regression coefficient for each market would estimate the same population regression coefficient. In other words would the slope of the demand curves in the different markets be the same? If so, the same regression coefficients could be used for all markets. To solve this test it was necessary to compute (1) the mean square of the difference in the sum of squares of deviations from a regression fitted to the pooled sum of squares and the sums of cross products for each of the markets, (2) the pooled sum of squares of deviations from regression fitted to the data for each market, and (3) the mean squares of the latter sum of squares. Calculation of an F value equal to 4.79 with 16 and 229 degrees of freedom (Test 2, Appendix Table 7) indicated that the same regression coefficients could not be used for the independent variables.

APPENDIX TABLE 7.—Calculation of Mean Squares Required for Testing Hypotheses Regarding Regression in Groups[1]

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F value
Total	249	150.5592		
Within	245	142.2940		
$\Sigma\Sigma d^2$	229	106.6071	.4655	
Test 1	20	43.9521	2.1976	4.72**
Test 2	16	35.6869	2.2304	4.79**

[1]Based on Chicago, Cleveland, Detroit, New York, and St. Louis consuming centers.
**Significant at the .01 level.

Elasticity of Demand

Elasticity of demand is generally stated as the percentage change in quantity associated with a 1 percent change in price. If the elasticity is less than unity (so that a given percentage change in price results in a smaller percentage change in quantity), the demand is inelastic. When the percentage change in price results in a greater percentage change in consumption, the demand is elastic. When proportionate changes occur, unitary elasticity exists.

Shepherd[3] states that valid estimates of elasticity of demand may be obtained by use of a least squares multiple regression analysis for which price is the dependent variable, and supply and some demand shifters are used as independent variables. An algebraic transformation must be made after the equation has been fitted to derive the appropriate coefficient of elasticity, since elasticity refers to a percentage change in quantity associated with a given change in price. The elasticity coefficient will differ somewhat depending on whether price or quantity is used as the dependent variable in the regression analysis. Only with a perfect r^2 by either method will the elasticities be the same.

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[3]Geoffrey S. Shepherd, *Agricultural Price Analysis* (Fourth Edition; Ames: The Iowa State College Press, 1957), p. 147.

Appendix Table 8 shows the elasticity of demand for sweet potatoes in several markets as determined in this study. The average elasticity of these markets is about –2.0. As price is increased by 1 percent, quantity will decrease by 2 percent.

Very few studies have been made concerning the elasticity of demand for sweet potatoes. Fox computed a production price coefficient of –.74 for sweet potatoes based on yearly data for 1922-41.[4] He stated that the elasticity of market demand may be decidedly different since a large portion of sweet potatoes produced are used on the farms where grown. Demand at the market level typically will be more elastic than at the farm level.

APPENDIX TABLE 8.–Elasticity of Demand for Sweet Potatoes in Specified Consuming Centers for the 1958-59 Marketing Season[1]

Consuming center	Elasticity of demand
Chicago	–1.94
St. Louis	–1.41
Cleveland	–1.30
Detroit	–2.61
New York City	–1.88
New Orleans	–2.21
Los Angeles	–2.47

[1] Based on least squares multiple regression analysis for which price is the dependent variable.

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[4] Karl A. Fox, "Factors Affecting Farm Income, Farm Prices, and Food Consumption." *Agricultural Economics Research,* III (July 1951), p. 77.

APPENDIX B

COSTS OF TRANSPORTING SWEET POTATOES FROM PRODUCING AREAS TO CONSUMING CENTERS

Sweet potatoes from all shipping areas can move to market by either rail or truck. However, almost all shipments are made by truck.[1] Therefore, transportation costs used in the present study were confined to truck transportation.

Since rates for shipping sweet potatoes are not regulated by the Interstate Commerce Commission, they could vary among areas and from time to time depending on the supply and demand for trucking services.[2] However, rates appear to be relatively stable over time. They also tend to be uniform both within and between areas.

Shipping rates were obtained from a survey of Louisiana shippers and truck brokers operating in the Louisiana sweet potato area. Truck rates from Louisiana to specified consuming centers are presented in Appendix Table 9. These rates were used in developing a rate model.

APPENDIX TABLE 9.—Motor Transportation Charges for Sweet Potatoes and Shipping Distance from Louisiana to Specified Consuming Centers, 1958-59 Season

Consuming center	Transportation charge		Shipping distance[2]
	Per crate	Per carload[1]	
	Dollars		*Miles*
Chicago	.55	275	995
Denver	.65	325	1,189
Louisville	.50	250	770
Boston	.90	450	1,673
Detroit	.65	325	1,137
Minneapolis-St. Paul	.70	350	1,191
Kansas City	.50	250	729
St. Louis	.45	225	753
Cincinnati	.55	275	881
Cleveland	.65	325	1,126
New York City	.80	400	1,451
Pittsburgh	.70	350	1,171
Philadelphia	.75	375	1,366

[1] The charges are based on 500 crates per carload.
[2] The mileage applies to the primary shipping point in the state, Opelousas, Louisiana

It was necessary to estimate rates for those routes used infrequently or for potential routes where rates were not available. To estimate these rates, estimating equations were derived from the rates used. Rates for all routes used in the study were then computed from the estimating equations.

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[1] Over the years there has been an almost complete shift from rail carriers to trucks for transporting sweet potatoes. This is attributed primarily to faster service offered by truckers, less need for rehandling, and greater flexibility in serving markets.

[2] The Interstate Commerce Act exempts motor carriers of agricultural commodities (including unmanufactured products thereof) from economic regulation by the Interstate Commerce Commission. Economic regulation includes control over who may engage in trucking, the routes or areas to be served, and the rates to be charged.

Estimating Equation

Transportation charges for shipping sweet potatoes from a given production area to a particular market depend on (1) the rate per mile and (2) the distance to market. To establish the relationship between transportation costs and distance, the general equation for transportation rates as a function of distance can be written:

$$Y = f(X),$$

where Y is transportation cost in dollars and X is the approximate highway mileage between shipping point and destination. Several forms of the regression technique were considered but it was found that the appropriate form of the general equation to use was:

$$Y = a + b_1X_1,$$

where Y is the transportation charge in dollars per carlot, a is the Y intercept, b_1 is the regression coefficient, and X_1 is the shipping distance in miles. This equation states that after a constant charge for loading and other fixed charges are paid, the transportation rate increases at a constant rate as distance is increased.

The results of the regression analysis gave the following estimates:

$$Y = 70.23 + .226X_1$$

The estimated b value was significant at the .01 level, and the equation explained 97.07 percent of the variation in transportation charges.

Interregional Transportation Costs

Unit costs of transportation between selected shipping points and consuming centers were computed by using the estimating equation developed in the previous section. These charges, based on 500 crates per carload, are shown in Appendix Table 10. It was necessary to compute costs from each producing area to all markets analyzed in the problem.

APPENDIX TABLE 10.—Estimated Cost of Transportation for Sweet Potatoes, By Shipping Points and Consuming Centers, 1958-59 Season

Consuming center	Shipping point					
	Ala. Cullman	Ariz. Phoenix	Ark. El Dorado	Cal. Atwater	Del. Salisbury[1]	Fla. Ft. Pierce
	Dollars per carlot equivalent[2]					
Atlanta	105	500	200	635	245	195
Baltimore	260	605	340	700	95	305
Birmingham	85	460	160	600	270	220
Boston	355	690	435	775	170	395
Chicago	210	475	245	550	250	355
Cincinnati	175	500	240	595	210	300
Cleveland	230	545	295	625	175	350
Dallas-Ft. Worth	230	310	135	500	415	355
Denver	370	260	295	335	465	530
Detroit	235	535	290	610	210	360
Kansas City	225	360	190	470	335	375
Los Angeles	535	160	460	130	700	685
Louisville	150	480	215	595	235	295
Minneapolis-St. Paul	295	470	285	510	345	440
New Orleans	165	420	145	565	355	250
New York-Newark	305	640	385	730	120	345
Philadelphia	285	620	365	715	100	325
Pittsburgh	235	555	305	650	145	330
Portland	660	390	625	235	755	815
St. Louis	175	420	180	530	280	320
San Francisco-Oakland	615	250	540	100	750	760
Washington, D. C.	255	605	335	700	100	295

Consuming center	Shipping point					
	Ga. Americus	Ill. Dongola	Ind. Owensville	Io. Muscatine	Kan. Manhattan	Ky. Dresden[3]
	Dollars per carlot equivalent					
Atlanta	100	180	170	250	280	155
Baltimore	250	270	240	265	340	265
Birmingham	120	170	165	240	260	135
Boston	340	355	320	340	420	355
Chicago	260	155	130	115	210	175
Cincinnati	205	155	125	175	230	155
Cleveland	260	210	180	195	275	210
Dallas-Ft. Worth	255	225	260	260	190	205
Denver	425	300	305	260	185	315
Detroit	265	215	180	175	265	215
Kansas City	285	155	165	145	95	175
Los Angeles	585	530	535	510	410	515
Louisville	200	130	100	175	215	130
Minneapolis-St. Paul	360	230	235	140	200	245
New Orleans	185	205	235	280	290	190
New York-Newark	290	305	275	300	370	305
Philadelphia	270	285	255	285	355	290
Pittsburgh	270	220	190	215	290	220
Portland	715	590	595	530	485	605
St. Louis	235	100	105	120	155	120
San Francisco-Oakland	660	585	590	525	475	595
Washington, D. C.	240	270	240	270	340	260

(Continued)

APPENDIX TABLE 10.—(Continued)

Consuming center	Shipping point					
	La. Opelousas	Md. Salisbury	Miss. Vardaman	Mo. Manchester	N. J. Vineland	N. M. Portales
			Dollars per carlot equivalent			
Atlanta	210	245	145	200	250	365
Baltimore	355	95	290	260	95	465
Birmingham	175	270	105	190	275	325
Boston	450	170	380	345	145	550
Chicago	275	250	225	140	245	350
Cincinnati	275	210	195	155	210	360
Cleveland	325	175	250	195	170	405
Dallas-Ft. Worth	155	415	185	220	420	175
Denver	325	465	350	265	465	180
Detroit	325	210	255	190	205	400
Kansas City	250	335	205	130	335	235
Los Angeles	485	700	510	495	710	305
Louisville	250	235	170	135	235	355
Minneapolis-St. Paul	350	345	295	205	340	340
New Orleans	100	355	150	235	360	290
New York-Newark	400	120	330	295	140	500
Philadelphia	375	100	315	275	95	485
Pittsburgh	350	145	260	210	140	420
Portland	630	755	125	550	750	445
St. Louis	225	280	170	75	280	280
San Francisco-Oakland	560	750	590	550	745	395
Washington, D. C.	345	100	280	260	105	465

Consuming center	Shipping point				
	N. C. Benson	S. C. Kingstree	Tenn. Dresden	Tex. Tyler	Va. Onley
			Dollars per carlot equivalent		
Atlanta	165	140	155	240	220
Baltimore	145	185	265	385	110
Birmingham	205	180	135	200	260
Boston	240	275	355	665	180
Chicago	265	270	175	285	270
Cincinnati	200	210	155	280	220
Cleveland	210	250	210	335	190
Dallas-Ft. Worth	355	330	205	95	405
Denver	470	465	315	275	480
Detroit	235	270	215	330	230
Kansas City	325	320	175	200	360
Los Angeles	685	660	515	420	715
Louisville	205	205	130	255	240
Minneapolis-St. Paul	360	365	245	305	365
New Orleans	300	255	190	165	335
New York-Newark	190	225	305	425	135
Philadelphia	170	230	290	405	115
Pittsburgh	180	220	220	355	160
Portland	760	755	605	580	770
St. Louis	265	260	120	220	300
San Francisco-Oakland	755	735	595	500	765
Washington, D. C.	140	175	260	375	110

[1] Salisbury, Maryland, was selected as the shipping point for Delaware and Maryland.

[2] These charges are based on 500 crates per carlot and are computed from estimates obtained from the regression analysis in the preceding section.

[3] Dresden, Tennessee, was selected as the shipping point for Kentucky and Tennessee.

APPENDIX C

OPTIMUM SHIPPING PATTERNS FOR INDIVIDUAL PRODUCING AREAS AND FOR THE INDUSTRY, BY MARKETING PERIODS

As explained in Appendix A, the analysis indicated distinct and consistent shifts in demand for sweet potatoes during the marketing season. One level of demand prevails during August, the beginning of the shipping season. A second level prevails during the six months of September, October, January, February, March, and April. A third level, the highest for the season, exists during the two months of November and December. Because of lack of sufficient observations, other months of the shipping season (May, June, and July) were not included in the analysis. For convenience, the August period, the six-month period, and the two-month period will be designated respectively as marketing periods 1, 2, and 3 in the appendix tables to follow.

Results for Louisiana are presented in Appendix Tables 11 through 19. Results for the industry as a whole are presented in Appendix Tables 20 through 25. Results for each individual producing area are presented in alphabetical order, by states, in Appendix Tables 26 through 71.

APPENDIX TABLE 11.—Results of Actual and Optimum Allocations of Existing Supplies of Louisiana Sweet Potatoes in 22 Major Markets, With Given Allocations From Competing Areas, Marketing Period 1, 1958-59 Season

Consuming center	Unloads		
	Actual, from areas other than Louisiana	From Louisiana	
		Actual	Optimum
	Carlot equivalents		
Atlanta	43		
Baltimore	31		
Birmingham	97		
Boston	18		
Chicago	2	43	
Cincinnati	9	11	
Cleveland	2	16	
Dallas-Ft. Worth	15		
Denver	5	6	111
Detroit		21	
Kansas City		9	
Los Angeles	85		
Louisville		7	
Minneapolis-St. Paul	1	1	
New Orleans		13	
New York-Newark	64	13	
Philadelphia	56	6	
Pittsburgh	17	10	
Portland	4		
St. Louis	7	15	
San Francisco-Oakland	29		65
Washington, D. C.	10	5	
Total unloads	495	176	176
Net revenue to Louisiana shippers		$350,568	$442,613

APPENDIX TABLE 12.—Results of Actual and Optimum Allocations of Existing Supplies of Louisiana Sweet Potatoes in 22 Major Markets, With Given Allocations From Competing Areas, Marketing Period 2, 1958-59 Season

Consuming center	Unloads		
	Actual, from areas other than Louisiana	From Louisiana	
		Actual	Optimum
	Carlot equivalents		
Atlanta	504		
Baltimore	408	12	
Birmingham	468		
Boston	246		
Chicago	90	552	402
Cincinnati	102	84	30
Cleveland	72	222	192
Dallas-Ft. Worth	330		
Denver	66	60	
Detroit	48	270	228
Kansas City	54	84	72
Los Angeles	834		72
Louisville	18	48	18
Minneapolis-St. Paul	24	48	162
New Orleans		270	156
New York-Newark	1,218	36	
Philadelphia	744	12	
Pittsburgh	234	84	30
Portland	72		156
St. Louis	96	132	66
San Francisco-Oakland	306		330
Washington, D. C.	216		
Total unloads	6,150	1,914	1,914
Net revenue to Louisiana shippers		$2,996,460	$3,391,038

APPENDIX TABLE 13.—Results of Actual and Optimum Allocations of Existing Supplies of Louisiana Sweet Potatoes in 22 Major Markets, With Given Allocations From Competing Areas, Marketing Period 3, 1958-59 Season

Consuming center	Unloads		
	Actual, from areas other than Louisiana	From Louisiana	
		Actual	Optimum
	Carlot equivalents		
Atlanta	176		
Baltimore	146	10	
Birmingham	128	2	
Boston	146	2	
Chicago	48	356	346
Cincinnati	56	42	36
Cleveland	40	110	108
Dallas-Ft. Worth	144		
Denver	68	6	4
Detroit	12	148	148
Kansas City	32	22	26
Los Angeles	504		
Louisville	6	28	20
Minneapolis-St. Paul	26	24	110
New Orleans		116	86
New York-Newark	648	28	
Philadelphia	334	4	
Pittsburgh	114	40	30
Portland	74		
St. Louis	34	72	64
San Francisco-Oakland	198		32
Washington, D. C.	86		
Total unloads	3,020	1,010	1,010
Net revenue to Louisiana shippers		$1,781,374	$1,862,664

APPENDIX TABLE 14.—Results of 50 Percent Increase in Sweet Potato Unloads From Louisiana, With Given Allocations From Competing Areas, 22 Major Markets, Marketing Period 1, 1958-59 Season

Consuming center	Unloads		
	Actual, from areas other than Louisiana	Optimum allocation from Louisiana	
		Existing supplies	Increased supplies
		Carlot equivalents	
Atlanta	43		
Baltimore	31		
Birmingham	97		
Boston	18		
Chicago	2		
Cincinnati	9		
Cleveland	2		5
Dallas-Ft. Worth	15		
Denver	5	111	133
Detroit			
Kansas City			
Los Angeles	85		
Louisville			4
Minneapolis-St. Paul	1		
New Orleans			
New York-Newark	64		
Philadelphia	56		
Pittsburgh	17		
Portland	4		
St. Louis	7		
San Francisco-Oakland	29	65	88
Washington, D. C.	10		34
Total unloads	495	176	264
Net revenue to Louisiana shippers		$442,613	$625,535

APPENDIX TABLE 15.—Results of 50 Percent Increase in Sweet Potato Unloads From Louisiana, With Given Allocations From Competing Areas, 22 Major Markets, Marketing Period 2, 1958-59 Season

Consuming center	Unloads		
	Actual, from areas other than Louisiana	Optimum allocation from Louisiana	
		Existing supplies	Increased supplies
		Carlot equivalents	
Atlanta	504		
Baltimore	408		
Birmingham	468		
Boston	246		
Chicago	90	402	516
Cincinnati	102	30	54
Cleveland	72	192	222
Dallas-Ft. Worth	330		
Denver	66		24
Detroit	48	228	294
Kansas City	54	72	102
Los Angeles	834	72	210
Louisville	18	18	48
Minneapolis-St. Paul	24	162	276
New Orleans		156	210
New York-Newark	1,218		
Philadelphia	744		
Pittsburgh	234	30	60
Portland	72	156	294
St. Louis	96	66	96
San Francisco-Oakland	306	330	462
Washington, D. C.	216		
Total unloads	6,150	1,914	2,868
Net revenue to Louisiana shippers		$3,391,038	$4,653,774

APPENDIX TABLE 16.—Results of 50 Percent Increase in Sweet Potato Unloads From Louisiana, With Given Allocations From Competing Areas, 22 Major Markets, Marketing Period 3, 1958-59 Season

Consuming center	Unloads		
	Actual, from areas other than Louisiana	Optimum allocation from Louisiana	
		Existing supplies	Increased supplies
		Carlot equivalents	
Atlanta	176		
Baltimore	146		
Birmingham	128		
Boston	146		
Chicago	48	346	406
Cincinnati	56	36	50
Cleveland	40	108	122
Dallas-Ft. Worth	144		
Denver	68	4	78
Detroit	12	148	182
Kansas City	32	26	42
Los Angeles	504		30
Louisville	6	20	36
Minneapolis-St. Paul	26	110	170
New Orleans		86	114
New York-Newark	648		
Philadelphia	334		
Pittsburgh	114	30	46
Portland	74		58
St. Louis	34	64	78
San Francisco-Oakland	198	32	104
Washington, D. C.	86		
Total unloads	3,020	1,010	1,516
Net revenue to Louisiana shippers		$1,862,664	$2,442,874

APPENDIX TABLE 17.—Effect of 50 Percent Increase in Louisiana Sweet Potato Shipments on Optimum Shipping Patterns for the Industry, Marketing Period 1, 1958-59 Season

Consuming center	Optimum unloads from areas other than Louisiana		Optimum unloads from Louisiana	
	Before increase in Louisiana shipments	After increase in Louisiana shipments	Before increase in Louisiana shipments	After increase in Louisiana shipments
		Carlot equivalents		
Atlanta	47	49		
Baltimore				
Birmingham	75	70		8
Boston				
Chicago	8	9		1
Cincinnati	3	3		
Cleveland	14	14		
Dallas-Ft. Worth	37	41		
Denver	1		127	153
Detroit	12	12		
Kansas City				3
Los Angeles	10	10	49	74
Louisville	7	7		
Minneapolis-St. Paul				
New Orleans				
New York-Newark				
Philadelphia				
Pittsburgh	21	21		
Portland	19	19		
St. Louis	5	3		5
San Francisco-Oakland	112	112		20
Washington, D. C.	124	125		
Total unloads	495	495	176	264
Net revenue to Louisiana shippers			$428,511	$599,961

APPENDIX TABLE 18.—Effect of 50 Percent Increase in Louisiana Sweet Potato Shipments on Optimum Shipping Patterns for the Industry, Marketing Period 2, 1958-59 Season

Consuming center	Optimum unloads from areas other than Louisiana		Optimum unloads from Louisiana	
	Before increase in Louisiana shipments	After increase in Louisiana shipments	Before increase in Louisiana shipments	After increase in Louisiana shipments
	Carlot equivalents			
Atlanta	480	504		
Baltimore				
Birmingham	414	384		54
Boston	36	114		
Chicago	348	72	282	630
Cincinnati	180	192		
Cleveland	324	330		
Dallas-Ft. Worth	306	336		
Denver	120	138		60
Detroit	390	414		
Kansas City	36		126	180
Los Angeles	186	138	882	1,014
Louisville	78	48		42
Minneapolis-St. Paul	12	36	312	360
New Orleans			216	246
New York-Newark	1,200	1,278		
Philadelphia	306	384		
Pittsburgh	330	342		
Portland	414	390		84
St. Louis	102	18	96	198
San Francisco-Oakland	882	942		
Washington, D. C.	6	90		
Total unloads	6,150	6,150	1,914	2,868
Net revenue to Louisiana shippers			$3,052,224	$4,311,144

APPENDIX TABLE 19.—Effect of 50 Percent Increase in Louisiana Sweet Potato Shipments on Optimum Shipping Patterns for the Industry, Marketing Period 3, 1958-59 Season

Consuming center	Optimum unloads from areas other than Louisiana		Optimum unloads from Louisiana	
	Before increase in Louisiana shipments	After increase in Louisiana shipments	Before increase in Louisiana shipments	After increase in Louisiana shipments
	Carlot equivalents			
Atlanta	162	160		14
Baltimore				
Birmingham	76		8	98
Boston	14	62		
Chicago	4		438	472
Cincinnati	88	62	16	50
Cleveland	162	166		2
Dallas-Ft. Worth	124	138		
Denver	86	92	44	74
Detroit	188	122		80
Kansas City	32	18	38	60
Los Angeles	450	368	70	188
Louisville	22		16	46
Minneapolis-St. Paul	2	2	182	212
New Orleans			108	122
New York-Newark	664	712		
Philadelphia	212	258		
Pittsburgh	164	170		
Portland	130	168		
St. Louis	20	20	90	98
San Francisco-Oakland	320	358		
Washington, D. C.	100	144		
Total unloads	3,020	3,020	1,010	1,516
Net revenue to Louisiana shippers			$1,673,558	$2,334,584

APPENDIX TABLE 20.—Net Revenue to Producing Areas for Existing Supplies of Sweet Potatoes Under Actual and Optimum Shipping Patterns for the Industry, Marketing Period 1, 1958-59 Season

Producing area	Shipping pattern		Net change from actual to optimum	
	Actual	Optimum		
	— — — — — —	*Dollars* — —	— — — —	*Percent*
Alabama	183,290	216,227	32,937	18.0
Arizona	28,690	24,831	- 3,859	-13.5
Arkansas	3,240	2,538	- 702	-21.7
California	313,375	320,432	7,057	2.3
Georgia	78,740	77,004	- 1,736	- 2.2
Louisiana	350,568	428,511	77,943	22.2
Maryland	41,940	50,877	8,937	21.3
Mississippi	38,223	52,763	14,540	38.0
Missouri	6,033	7,566	1,533	25.4
New Jersey	1,770	2,314	544	30.7
New Mexico	2,875	2,614	- 261	- 9.1
North Carolina	27,429	32,729	5,300	19.3
South Carolina	12,391	11,830	- 561	- 4.5
Tennessee	8,011	9,864	1,853	23.1
Texas	49,641	46,404	- 3,237	- 6.5
Virginia	304,847	378,376	73,529	24.1
Total	1,451,063	1,664,880	213,817	14.7

APPENDIX TABLE 21.—Net Revenue to Producing Areas for Existing Supplies of Sweet Potatoes Under Actual and Optimum Shipping Patterns for the Industry, Marketing Period 2, 1958-59 Season

Producing area	Shipping pattern		Net change from actual to optimum	
	Actual	Optimum		
	— — — — — —	*Dollars* — —	— — — —	*Percent*
Alabama	684,078	750,072	65,994	9.6
Arizona	47,856	57,570	9,714	20.3
Arkansas	9,756	9,900	144	1.5
California	2,753,880	2,340,552	-413,328	-15.0
Delaware	7,158	9,852	2,694	37.6
Georgia	432,810	451,170	18,360	4.2
Indiana	9,870	10,434	564	5.7
Iowa	12,756	10,770	- 1,986	-15.6
Kansas	78,456	73,350	- 5,106	- 6.5
Louisiana	2,996,460	3,052,224	55,764	1.9
Maryland	695,334	788,352	93,018	13.4
Mississippi	163,236	211,242	48,006	29.4
Missouri	104,874	114,774	9,900	9.4
New Jersey	2,137,968	2,364,144	226,176	10.6
New Mexico	55,656	63,864	8,208	14.7
North Carolina	1,082,490	1,162,932	80,442	7.4
South Carolina	78,204	88,074	9,870	12.6
Tennessee	68,070	71,148	3,078	4.5
Texas	850,068	894,258	44,190	5.2
Virginia	933,210	1,044,534	111,324	11.9
Total	13,202,190	13,569,216	367,026	2.8

APPENDIX TABLE 22.—Net Revenue to Producing Areas for Existing Supplies of Sweet Potatoes Under Actual and Optimum Shipping Patterns for the Industry, Marketing Period 3, 1958-59 Season

Producing area	Shipping pattern		Net change from actual to optimum	
	Actual	Optimum		
	Dollars			Percent
Alabama	149,600	192,424	42,824	28.6
Arizona	119,518	134,368	14,850	12.4
Arkansas	3,760	3,474	– 286	– 7.6
California	1,680,108	1,565,544	–114,564	– 6.8
Delaware	3,524	3,572	48	1.4
Florida	2,440	3,320	880	36.1
Georgia	173,310	186,030	12,720	7.3
Illinois	3,690	3,550	– 140	– 3.8
Indiana	3,906	3,600	– 306	– 7.8
Iowa	4,744	3,704	– 1,040	–21.9
Kansas	58,160	50,960	– 7,200	–12.4
Kentucky	3,736	3,590	– 146	– 3.9
Louisiana	1,781,374	1,673,558	–107,816	– 6.1
Maryland	284,100	325,052	40,952	14.4
Mississippi	31,526	38,124	6,598	20.9
Missouri	37,400	36,200	– 1,200	– 3.2
New Jersey	1,393,146	1,482,588	89,442	6.4
New Mexico	20,622	25,634	5,012	24.3
North Carolina	554,212	574,946	20,734	3.7
South Carolina	45,104	48,060	2,956	6.6
Tennessee	21,222	21,540	318	1.5
Texas	377,950	399,424	21,474	5.7
Virginia	385,038	421,498	36,460	9.5
Total	7,138,190	7,200,760	62,570	.9

APPENDIX TABLE 23.—Effect of 50 Percent Increase in Louisiana Sweet Potato Shipments on Net Revenue to Specified Producing Areas, With Optimum Shipping Patterns for the Industry, Marketing Period 1, 1958-59 Season

Producing area	Net revenue		Change in net revenue when Louisiana supplies are increased
	With existing supplies	With increased supplies from Louisiana	
		Dollars	
Alabama	216,227	211,419	– 4,808
Arizona	24,831	23,373	– 1,458
Arkansas	2,538	2,469	– 69
California	320,432	305,872	–14,560
Georgia	77,004	75,904	– 1,100
Louisiana	428,511	599,961	171,450
Maryland	50,877	50,708	– 169
Mississippi	52,763	52,763	0
Missouri	7,566	7,296	– 270
New Jersey	2,314	2,314	0
New Mexico	2,614	2,452	– 162
North Carolina	32,729	32,355	– 374
South Carolina	11,830	11,660	– 170
Tennessee	9,864	9,596	– 268
Texas	46,404	45,162	– 1,242
Virginia	378,376	377,880	– 496
Total	1,664,880	1,811,184	146,304

APPENDIX TABLE 24.—Effect of 50 Percent Increase in Louisiana Sweet Potato Shipments on Net Revenue to Specified Producing Areas, With Optimum Shipping Patterns for the Industry, Marketing Period 2, 1958-59 Season

Producing area	Net revenue		Change in net revenue when Louisiana supplies are increased
	With existing supplies	With increased supplies from Louisiana	
		Dollars	
Alabama	750,072	719,100	– 30,972
Arizona	57,570	54,840	– 2,730
Arkansas	9,900	9,342	– 558
California	2,340,552	2,262,882	– 77,670
Delaware	9,852	9,546	– 306
Georgia	451,170	432,810	– 18,360
Indiana	10,434	9,876	– 558
Iowa	10,770	10,212	– 558
Kansas	73,350	69,636	– 3,714
Louisiana	3,052,224	4,311,144	1,258,920
Maryland	788,352	763,680	– 24,672
Mississippi	211,242	204,612	– 6,630
Missouri	114,774	108,234	– 6,540
New Jersey	2,364,144	2,294,466	– 69,678
New Mexico	63,864	60,696	– 3,168
North Carolina	1,162,932	1,117,740	– 45,192
South Carolina	88,074	84,402	– 3,672
Tennessee	71,148	67,242	– 3,906
Texas	894,258	847,392	– 46,866
Virginia	1,044,534	1,011,792	– 32,742
Total	13,569,216	14,449,644	880,428

APPENDIX TABLE 25.—Effect of 50 Percent Increase in Louisiana Sweet Potato Shipments on Net Revenue to Specified Producing Areas, With Optimum Shipping Patterns for the Industry, Marketing Period 3, 1958-59 Season

Producing area	Net revenue		Change in net revenue when Louisiana supplies are increased
	With existing supplies	With increased supplies from Louisiana	
		Dollars	
Alabama	192,424	180,494	– 11,930
Arizona	134,368	126,412	– 7,956
Arkansas	3,474	3,234	– 240
California	1,565,544	1,471,030	– 94,514
Delaware	3,572	3,384	– 188
Florida	3,320	3,114	– 206
Georgia	186,030	175,112	– 10,918
Illinois	3,550	3,310	– 240
Indiana	3,600	3,384	– 216
Iowa	3,704	3,470	– 234
Kansas	50,960	47,684	– 3,276
Kentucky	3,590	3,314	– 276
Louisiana	1,673,558	2,334,584	661,026
Maryland	325,052	307,944	– 17,108
Mississippi	38,124	35,910	– 2,214
Missouri	36,200	33,800	– 2,400
New Jersey	1,482,588	1,403,592	– 78,996
New Mexico	25,634	23,996	– 1,638
North Carolina	574,946	553,354	– 21,592
South Carolina	48,060	44,904	– 3,156
Tennessee	21,540	19,860	– 1,680
Texas	399,424	371,818	– 27,606
Virginia	421,498	399,126	– 22,372
Total	7,200,760	7,552,830	352,070

APPENDIX TABLE 26.—Carlot Unloads of Alabama Sweet Potatoes and Estimated Revenue Resulting from Actual and Optimum[1] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Carlot equivalents			
Atlanta	2		18	30	2	34
Baltimore						
Birmingham	87	75	420	414	108	76
Boston						
Chicago				6		
Cincinnati			6			
Cleveland						
Dallas-Ft. Worth		14				
Denver						
Detroit						
Kansas City						
Los Angeles						
Louisville			6			
Minneapolis-St. Paul						
New Orleans						
New York-Newark						
Philadelphia						
Pittsburgh						
Portland						
St. Louis						
San Francisco-Oakland						
Washington, D. C.						
Total unloads	89	89	450	450	110	110
Net revenue (dollars)	183,290	216,227	684,078	750,072	149,600	192,424

[1] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

APPENDIX TABLE 27.—Estimated Net Prices[1] Per Carload of Sweet Potatoes to Alabama Shippers Resulting from Actual and Optimum[2] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Dollars			
Atlanta	2,470*	2,401	1,598*	1,666*	1,630*	1,750*
Baltimore	1,590	1,711	1,028	1,301	1,155	1,459
Birmingham	2,050*	2,427	1,513*	1,667*	1,355*	1,749*
Boston	1,650	1,720	1,278	1,415	1,295	1,557
Chicago	2,065	2,352	1,643	1,659*	1,868	1,720
Cincinnati	1,825	2,343	1,595*	1,625	1,848	1,756
Cleveland	2,145	2,267	1,715	1,563	1,903	1,720
Dallas-Ft. Worth	2,820	2,443*	1,452	1,521	1,418	1,589
Denver	3,165	2,405	1,551	1,558	1,805	1,623
Detroit	2,155	2,284	1,769	1,597	1,938	1,737
Kansas City	2,120	2,391	1,738	1,617	1,942	1,702
Los Angeles	2,215	2,384	1,797	1,544	1,653	1,601
Louisville	2,381	2,381	1,714*	1,654	1,835	1,775
Minneapolis-St. Paul	2,101	2,117	1,966	1,640	2,217	1,697
New Orleans	1,850	2,073	1,382	1,537	1,533	1,601
New York-Newark	1,605	1,905	1,421	1,457	1,577	1,601
Philadelphia	1,630	1,872	1,141	1,434	1,330	1,575
Pittsburgh	2,041	2,224	1,615	1,554	1,827	1,675
Portland	2,340	2,242	1,907	1,536	1,765	1,583
St. Louis	1,911	2,422	1,489	1,639	1,770	1,710
San Francisco-Oakland	2,885	2,346	2,069	1,445	1,889	1,493
Washington, D. C.	2,571	2,146	1,339	1,475	1,637	1,610

[1] Wholesale price less transportation costs.

[2] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

*Denotes consuming centers that received shipments, or would have received shipments from Alabama under the optimum situation.

APPENDIX TABLE 28.—Carlot Unloads of Arizona Sweet Potatoes and Estimated Revenue Resulting from Actual and Optimum[1] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

	Marketing periods					
Consuming center	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Carlot equivalents			
Atlanta						
Baltimore						
Birmingham						
Boston						
Chicago						
Cincinnati			12		28	
Cleveland						
Dallas-Ft. Worth						
Denver	4		6		30	
Detroit						
Kansas City			6		4	
Los Angeles	1	9	6	30	2	68
Louisville						
Minneapolis-St. Paul						
New Orleans						
New York-Newark						
Philadelphia						
Pittsburgh						
Portland					4	
St. Louis						
San Francisco-Oakland	4					
Washington, D. C.						
Total unloads	9	9	30	30	68	68
Net revenue (dollars)	28,690	24.831	47.856	57,570	119,518	134,368

[1] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

APPENDIX TABLE 29.—Estimated Net Prices[1] Per Carload of Sweet Potatoes to Arizona Shippers Resulting from Actual and Optimum[2] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

	Marketing periods					
Consuming center	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Dollars			
Atlanta	2,075	2,006	1,203	1,271	1,235	1,355
Baltimore	1,245	1,366	683	956	810	1,114
Birmingham	1,675	2,052	1,138	1,292	980	1,374
Boston	1,315	1,385	943	1,080	960	1,222
Chicago	1,800	2,087	1,378	1,394	1,603	1,455
Cincinnati	1,500	2,018	1,270*	1,300	1,523*	1,431
Cleveland	1,830	1,952	1,400	1,248	1,588	1,405
Dallas-Ft. Worth	2,740	2,363	1,372	1,441	1,338	1,509
Denver	3,275*	2,515	1,661*	1,668	1,915*	1,733
Detroit	1,855	1,984	1,469	1,297	1,638	1,437
Kansas City	1,985	2,256	1,603*	1,482	1,807*	1,567
Los Angeles	2,590*	2,759*	2,172*	1,919*	2,028*	1,976*
Louisville	2,051	2,051	1,384	1,324	1,505	1,445
Minneapolis-St. Paul	1,926	1,942	1,791	1,465	2,042	1,522
New Orleans	1,595	1,818	1,127	1,282	1,278	1,346
New York-Newark	1,270	1,570	1,086	1,122	1,242	1,266
Philadelphia	1,295	1,537	806	1,099	995	1,240
Pittsburgh	1,721	1,904	1,295	1,234	1,507	1,355
Portland	2,610	2,512	2,177	1,806	2,035*	1,853
St. Louis	1,666	2,177	1,244	1,394	1,525	1,465
San Francisco-Oakland	3,250*	2,711	2,434	1,810	2,254	1,858
Washington, D. C.	2,221	1,796	989	1,125	1,287	1,260

[1] Wholesale price less transportation costs.

[2] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

*Denotes consuming centers that received shipments, or would have received shipments from Arizona under the optimum situation.

APPENDIX TABLE 30.—Carlot Unloads of Arkansas Sweet Potatoes and Estimated Revenue Resulting from Actual and Optimum[1] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Carlot equivalents			
Atlanta						
Baltimore						
Birmingham						
Boston						
Chicago						
Cincinnati						
Cleveland						
Dallas-Ft. Worth		1				
Denver	1		6		2	
Detroit						
Kansas City						2
Los Angeles						
Louisville						
Minneapolis-St. Paul				6		
New Orleans						
New York-Newark						
Philadelphia						
Pittsburgh						
Portland						
St. Louis						
San Francisco-Oakland						
Washington, D. C.						
Total unloads	1	1	6	6	2	2
Net revenue (dollars)	3,240	2,538	9,756	9,900	3,760	3,474

[1] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

APPENDIX TABLE 31.—Estimated Net Prices[1] Per Carload of Sweet Potatoes to Arkansas Shippers Resulting from Actual and Optimum[2] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Dollars			
Atlanta	2,375	2,306	1,503	1,571	1,535	1,655
Baltimore	1,510	1,631	948	1,221	1,075	1,379
Birmingham	1,975	2,352	1,438	1,592	1,280	1,674
Boston	1,570	1,640	1,198	1,335	1,215	1,477
Chicago	2,030	2,317	1,608	1,624	1,833	1,685
Cincinnati	1,760	2,278	1,530	1,560	1,783	1,691
Cleveland	2,080	2,202	1,650	1,498	1,838	1,655
Dallas-Ft. Worth	2,915	2,538*	1,547	1,616	1,513	1,684
Denver	3,240*	2,480	1,626*	1,633	1,880*	1,698
Detroit	2,100	2,229	1,714	1,542	1,833	1,682
Kansas City	2,155	2,426	1,773	1,652	1,977	1,737*
Los Angeles	2,290	2,459	1,872	1,619	1,728	1,676
Louisville	2,316	2,316	1,649	1,589	1,770	1,710
Minneapolis-St. Paul	2,111	2,127	1,976	1,650*	2,227	1,707
New Orleans	1,870	2,093	1,402	1,557	1,553	1,621
New York-Newark	1,525	1,825	1,341	1,377	1,497	1,521
Philadelphia	1,550	1,792	1,061	1,354	1,250	1,495
Pittsburgh	1,971	2,154	1,545	1,484	1,757	1,605
Portland	2,375	2,277	1,942	1,571	1,800	1,618
St. Louis	1,906	2,417	1,484	1,634	1,765	1,705
San Francisco-Oakland	2,960	2,421	2,144	1,520	1,964	1,568
Washington, D. C.	2,491	2,066	1,259	1,395	1,557	1,530

[1] Wholesale price less transportation costs.

[2] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

*Denotes consuming centers that received shipments, or would have received shipments from Arkansas under the optimum situation.

APPENDIX TABLE 32.—Carlot Unloads of California Sweet Potatoes and Estimated Revenue Resulting from Actual and Optimum[1] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Carlot equivalents			
Atlanta						
Baltimore						
Birmingham						
Boston						
Chicago						
Cincinnati						
Cleveland						
Dallas-Ft. Worth						
Denver					12	
Detroit						
Kansas City						
Los Angeles	84		828		502	348
Louisville						
Minneapolis-St. Paul						
New Orleans						
New York-Newark						
Philadelphia						
Pittsburgh						
Portland	3		60	312	68	112
St. Louis						
San Francisco-Oakland	25	112	306	882	198	320
Washington, D. C.						
Total unloads	112	112	1,194	1,194	780	780
Net revenue (dollars)	313,375	320,432	2,753,880	2,340,552	1,680,108	1,565,544

[1] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

APPENDIX TABLE 33.—Estimated Net Prices[1] Per Carload of Sweet Potatoes to California Shippers Resulting from Actual and Optimum[2] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Dollars			
Atlanta	1,940	1,871	1,068	1,136	1,100	1,220
Baltimore	1,150	1,271	588	861	715	1,019
Birmingham	1,535	1,912	998	1,152	840	1,234
Boston	1,230	1,300	858	995	875	1,137
Chicago	1,725	2,012	1,303	1,319	1,528	1,380
Cincinnati	1,405	1,923	1,175	1,205	1,428	1,336
Cleveland	1,750	1,872	1,320	1,168	1,508	1,325
Dallas-Ft. Worth	2,550	2,173	1,182	1,251	1,148	1,319
Denver	3,200	2,440	1,586	1,593	1,840*	1,658
Detroit	1,780	1,909	1,394	1,222	1,563	1,362
Kansas City	1,875	2,146	1,493	1,372	1,697	1,457
Los Angeles	2,620*	2,789	2,202*	1,949	2,058*	2,006*
Louisville	1,936	1,936	1,269	1,209	1,390	1,330
Minneapolis-St. Paul	1,886	1,902	1,751	1,425	2,002	1,482
New Orleans	1,450	1,673	982	1,137	1,133	1,201
New York-Newark	1,180	1,480	996	1,032	1,152	1,176
Philadelphia	1,200	1,442	711	1,004	900	1,145
Pittsburgh	1,626	1,809	1,200	1,139	1,412	1,260
Portland	2,765*	2,667	2,332*	1,961*	2,190*	2,008*
St. Louis	1,556	2,067	1,134	1,284	1,415	1,355
San Francisco-Oakland	3,400*	2,861*	2,584*	1,960*	2,404*	2,008*
Washington, D. C.	1,180	1,701	894	1,030	1,192	1,165

[1] Wholesale price less transportation costs.

[2] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

*Denotes consuming centers that received shipments, or would have received shipments from California under the optimum situation.

APPENDIX TABLE 34.—Carlot Unloads of Delaware Sweet Potatoes and Estimated Revenue Resulting from Actual and Optimum[1] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Carlot equivalents			
Atlanta						
Baltimore			6			
Birmingham						
Boston						
Chicago						
Cincinnati						
Cleveland						
Dallas-Ft. Worth						
Denver						
Detroit						
Kansas City						
Los Angeles						
Louisville						
Minneapolis-St. Paul						
New Orleans						
New York-Newark				6	2	2
Philadelphia						
Pittsburgh						
Portland						
St. Louis						
San Francisco-Oakland						
Washington, D. C.						
Total unloads			6	6	2	2
Net revenue (dollars)			7,158	9,852	3,524	3,572

[1]The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

APPENDIX TABLE 35.—Estimated Net Prices[1] Per Carload of Sweet Potatoes to Delaware Shippers Resulting from Actual and Optimum[2] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Dollars			
Atlanta			1,458	1,526	1,490	1,610
Baltimore			1,193*	1,466	1,320	1,624
Birmingham			1,328	1,482	1,170	1,564
Boston			1,463	1,600	1,480	1,742
Chicago			1,603	1,619	1,828	1,680
Cincinnati			1,560	1,590	1,813	1,721
Cleveland			1,770	1,618	1,958	1,775
Dallas-Ft. Worth			1,267	1,336	1,233	1,404
Denver			1,456	1,463	1,710	1,528
Detroit			1,794	1,622	1,963	1,762
Kansas City			1,628	1,507	1,832	1,592
Los Angeles			1,632	1,379	1,488	1,436
Louisville			1,629	1,569	1,750	1,690
Minneapolis-St. Paul			1,916	1,590	2,167	1,647
New Orleans			1,192	1,347	1,343	1,411
New York-Newark			1,606	1,642*	1,762*	1,786*
Philadelphia			1,326	1,619	1,515	1,760
Pittsburgh			1,705	1,644	1,917	1,765
Portland			1,812	1,441	1,670	1,488
St. Louis			1,384	1,534	1,665	1,605
San Francisco-Oakland			1,934	1,310	1,754	1,358
Washington, D. C.			1,494	1,630	1,792	1,765

[1]Wholesale price less transportation costs.

[2]The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

*Denotes consuming centers that received shipments, or would have received shipments from Delaware under the optimum situation.

APPENDIX TABLE 36.—Carlot Unloads of Florida Sweet Potatoes and Estimated Revenue Resulting from Actual and Optimum[1] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Carlot equivalents			
Atlanta						2
Baltimore						
Birmingham					2	
Boston						
Chicago						
Cincinnati						
Cleveland						
Dallas-Ft. Worth						
Denver						
Detroit						
Kansas City						
Los Angeles						
Louisville						
Minneapolis-St. Paul						
New Orleans						
New York-Newark						
Philadelphia						
Pittsburgh						
Portland						
St. Louis						
San Francisco-Oakland						
Washington, D. C.						
Total unloads					2	2
Net revenue (dollars)					2,440	3,320

[1] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

APPENDIX TABLE 37.—Estimated Net Prices[1] Per Carload of Sweet Potatoes to Florida Shippers Resulting from Actual and Optimum[2] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Dollars			
Atlanta					1,540	1,660*
Baltimore					1,110	1,414
Birmingham					1,220*	1,614
Boston					1,255	1,517
Chicago					1,723	1,575
Cincinnati					1,723	1,631
Cleveland					1,783	1,600
Dallas-Ft. Worth					1,293	1,464
Denver					1,645	1,463
Detroit					1,813	1,612
Kansas City					1,792	1,552
Los Angeles					1,503	1,451
Louisville					1,690	1,630
Minneapolis-St. Paul					2,072	1,552
New Orleans					1,448	1,516
New York-Newark					1,537	1,561
Philadelphia					1,290	1,535
Pittsburgh					1,732	1,580
Portland					1,610	1,428
St. Louis					1,625	1,565
San Francisco-Oakland					1,744	1,348
Washington, D. C.					1,597	1,570

[1] Wholesale price less transportation costs.

[2] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

*Denotes consuming centers that received shipments, or would have received shipments from Florida under the optimum situation.

APPENDIX TABLE 38.—Carlot Unloads of Georgia Sweet Potatoes and Estimated Revenue Resulting from Actual and Optimum[1] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Carlot equivalents			
Atlanta	31	31	270	270	106	106
Baltimore						
Birmingham	1					
Boston						
Chicago						
Cincinnati						
Cleveland		1				
Dallas-Ft. Worth						
Denver						
Detroit						
Kansas City						
Los Angeles						
Louisville						
Minneapolis-St. Paul						
New Orleans						
New York-Newark						
Philadelphia						
Pittsburgh						
Portland						
St. Louis						
San Francisco-Oakland						
Washington, D. C.						
Total unloads	32	32	270	270	106	106
Net revenue (dollars)	78,740	77,004	432,810	451,170	173,310	186,030

[1] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

APPENDIX TABLE 39.—Estimated Net Prices[1] Per Carload of Sweet Potatoes to Georgia Shippers Resulting from Actual and Optimum[2] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Dollars			
Atlanta	2,475*	2,406*	1,603*	1,671*	1,635*	1,755*
Baltimore	1,600	1,721	1,038	1,311	1,165	1,469
Birmingham	2,015*	2,392	1,478	1,632	1,320	1,714
Boston	1,665	1,735	1,293	1,430	1,310	1,572
Chicago	2,015	2,302	1,593	1,609	1,818	1,670
Cincinnati	1,795	2,313	1,565	1,595	1,818	1,726
Cleveland	2,115	2,237	1,685	1,533	1,873	1,690
Dallas-Ft. Worth	2,795	2,418*	1,427	1,496	1,393	1,564
Denver	3,110	2,350	1,496	1,503	1,750	1,568
Detroit	2,125	2,254	1,739	1,567	1,908	1,707
Kansas City	2,060	2,331	1,678	1,557	1,882	1,642
Los Angeles	2,165	2,334	1,747	1,494	1,603	1,551
Louisville	2,331	2,331	1,664	1,604	1,785	1,725
Minneapolis-St. Paul	2,036	2,052	1,901	1,575	2,152	1,632
New Orleans	1,830	2,053	1,362	1,517	1,513	1,581
New York-Newark	1,620	1,920	1,436	1,472	1,592	1,616
Philadelphia	1,645	1,887	1,156	1,449	1,345	1,590
Pittsburgh	2,006	2,189	1,580	1,519	1,792	1,640
Portland	2,285	2,187	1,852	1,481	1,710	1,528
St. Louis	1,851	2,362	1,429	1,579	1,710	1,650
San Francisco-Oakland	2,840	2,301	2,024	1,400	1,844	1,448
Washington, D. C.	2,586	2,161	1,354	1,490	1,652	1,625

[1] Wholesale price less transportation costs.

[2] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

*Denotes consuming centers that received shipments, or would have received shipments from Georgia under the optimum situation.

APPENDIX TABLE 40.—Carlot Unloads of Illinois Sweet Potatoes and Estimated Revenue Resulting from Actual and Optimum[1] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Carlot equivalents			
Atlanta						
Baltimore						
Birmingham						
Boston						
Chicago						2
Cincinnati						
Cleveland						
Dallas-Ft. Worth						
Denver						
Detroit						
Kansas City						
Los Angeles						
Louisville						
Minneapolis-St. Paul						
New Orleans						
New York-Newark						
Philadelphia						
Pittsburgh						
Portland						
St. Louis					2	
San Francisco-Oakland						
Washington, D. C.						
Total unloads					2	2
Net revenue (dollars)					3,690	3,550

[1] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

APPENDIX TABLE 41.—Estimated Net Prices[1] Per Carload of Sweet Potatoes to Illinois Shippers Resulting from Actual and Optimum[2] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Dollars			
Atlanta					1,555	1,675
Baltimore					1,145	1,449
Birmingham					1,270	1,664
Boston					1,295	1,557
Chicago					1,923	1,775*
Cincinnati					1,868	1,776
Cleveland					1,923	1,740
Dallas-Ft. Worth					1,423	1,594
Denver					1,875	1,693
Detroit					1,958	1,757
Kansas City					2,012	1,772
Los Angeles					1,658	1,606
Louisville					1,855	1,795
Minneapolis-St. Paul					2,282	1,762
New Orleans					1,493	1,561
New York-Newark					1,577	1,601
Philadelphia					1,330	1,575
Pittsburgh					1,842	1,690
Portland					1,835	1,653
St. Louis					1,845*	1,785
San Francisco-Oakland					1,919	1,523
Washington, D. C.					1,622	1,595

[1] Wholesale price less transportation costs.

[2] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

*Denotes consuming centers that received shipments, or would have received shipments from Illinois under the optimum situation.

APPENDIX TABLE 42.—Carlot Unloads of Indiana Sweet Potatoes and Estimated Revenue Resulting from Actual and Optimum[1] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Carlot equivalents			
Atlanta						
Baltimore						
Birmingham						
Boston						
Chicago				6		2
Cincinnati			6			
Cleveland					2	
Dallas-Ft. Worth						
Denver						
Detroit						
Kansas City						
Los Angeles						
Louisville						
Minneapolis-St. Paul						
New Orleans						
New York-Newark						
Philadelphia						
Pittsburgh						
Portland						
St. Louis						
San Francisco-Oakland						
Washington, D. C.						
Total unloads			6	6	2	2
Net revenue (dollars)			9,870	10,434	3,906	3,600

[1]The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

APPENDIX TABLE 43.—Estimated Net Prices[1] Per Carload of Sweet Potatoes to Indiana Shippers Resulting from Actual and Optimum[2] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Dollars			
Atlanta			1,533	1,601	1,565	1,685
Baltimore			1,048	1,321	1,175	1,479
Birmingham			1,433	1,587	1,275	1,669
Boston			1,313	1,450	1,330	1,592
Chicago			1,723	1,739*	1,948	1,800*
Cincinnati			1,645*	1,675	1,898	1,806
Cleveland			1,765	1,613	1,953*	1,770
Dallas-Ft. Worth			1,422	1,491	1,388	1,559
Denver			1,616	1,623	1,870	1,688
Detroit			1,824	1,652	1,993	1,792
Kansas City			1,798	1,677	2,002	1,762
Los Angeles			1,797	1,544	1,653	1,601
Louisville			1,764	1,704	1,885	1,825
Minneapolis-St. Paul			2,026	1,700	2,277	1,757
New Orleans			1,312	1,467	1,463	1,531
New York-Newark			1,451	1,487	1,607	1,631
Philadelphia			1,171	1,464	1,360	1,605
Pittsburgh			1,660	1,599	1,872	1,720
Portland			1,972	1,601	1,830	1,648
St. Louis			1,559	1,709	1,840	1,780
San Francisco-Oakland			2,094	1,470	1,914	1,518
Washington, D. C.			1,354	1,490	1,652	1,625

[1]Wholesale price less transportation costs.

[2]The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

*Denotes consuming centers that received shipments, or would have received shipments from Indiana under the optimum situation.

APPENDIX TABLE 44.—Carlot Unloads of Iowa Sweet Potatoes and Estimated Revenue Resulting from Actual and Optimum[1] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Carlot equivalents			
Atlanta						
Baltimore						
Birmingham						
Boston						
Chicago						
Cincinnati						
Cleveland						
Dallas-Ft. Worth						
Denver						
Detroit						
Kansas City						
Los Angeles						
Louisville						
Minneapolis-St. Paul			6	6	2	2
New Orleans						
New York-Newark						
Philadelphia						
Pittsburgh						
Portland						
St. Louis						
San Francisco-Oakland						
Washington, D. C.						
Total unloads			6	6	2	2
Net revenue (dollars)			12,756	10,770	4,744	3,704

[1] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

APPENDIX TABLE 45.—Estimated Net Prices[1] Per Carload of Sweet Potatoes to Iowa Shippers Resulting from Actual and Optimum[2] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Dollars			
Atlanta			1,453	1,521	1,485	1,605
Baltimore			1,023	1,296	1,150	1,454
Birmingham			1,358	1,512	1,200	1,594
Boston			1,293	1,430	1,310	1,572
Chicago			1,738	1,754	1,963	1,815
Cincinnati			1,595	1,625	1,848	1,756
Cleveland			1,750	1,598	1,938	1,755
Dallas-Ft. Worth			1,422	1,491	1,388	1,559
Denver			1,661	1,668	1,915	1,733
Detroit			1,829	1,657	1,998	1,797
Kansas City			1,818	1,697	2,022	1,782
Los Angeles			1,822	1,569	1,678	1,626
Louisville			1,689	1,629	1,810	1,750
Minneapolis-St. Paul			2,121*	1,795*	2,372*	1,852*
New Orleans			1,267	1,422	1,418	1,486
New York-Newark			1,426	1,462	1,582	1,606
Philadelphia			1,141	1,434	1,330	1,575
Pittsburgh			1,635	1,574	1,847	1,695
Portland			2,037	1,666	1,895	1,713
St. Louis			1,544	1,694	1,825	1,765
San Francisco-Oakland			2,159	1,535	1,979	1,583
Washington, D. C.			1,324	1,460	1,622	1,595

[1] Wholesale price less transportation costs.

[2] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

*Denotes consuming centers that received shipments, or would have received shipments from Iowa under the optimum situation.

APPENDIX TABLE 46.—Carlot Unloads of Kansas Sweet Potatoes and Estimated Revenue Resulting from Actual and Optimum[1] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Carlot equivalents			
Atlanta						
Baltimore						
Birmingham						
Boston						
Chicago					4	
Cincinnati						
Cleveland						
Dallas-Ft. Worth						
Denver				6		14
Detroit						
Kansas City			42	36	20	14
Los Angeles						
Louisville						
Minneapolis-St. Paul					4	
New Orleans						
New York-Newark						
Philadelphia						
Pittsburgh						
Portland						
St. Louis						
San Francisco-Oakland						
Washington, D. C.						
Total unloads			42	42	28	28
Net revenue (dollars)			78,456	73,350	58,160	50,960

[1]The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

APPENDIX TABLE 47.—Estimated Net Prices[1] Per Carload of Sweet Potatoes to Kansas Shippers Resulting from Actual and Optimum[2] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Dollars			
Atlanta			1,423	1,491	1,455	1,575
Baltimore			948	1,221	1,075	1,379
Birmingham			1,338	1,492	1,180	1,574
Boston			1,213	1,350	1,230	1,492
Chicago			1,643	1,659	1,868*	1,720
Cincinnati			1,540	1,570	1,793	1,701
Cleveland			1,670	1,518	1,858	1,675
Dallas-Ft. Worth			1,492	1,561	1,458	1,629
Denver			1,736	1,743*	1,990	1,808*
Detroit			1,739	1,567	1,908	1,707
Kansas City			1,868*	1,747*	2,072*	1,832*
Los Angeles			1,922	1,669	1,778	1,726
Louisville			1,649	1,589	1,770	1,710
Minneapolis-St. Paul			2,061	1,735	2,312*	1,792
New Orleans			1,257	1,412	1,408	1,476
New York-Newark			1,356	1,392	1,512	1,536
Philadelphia			1,071	1,364	1,260	1,505
Pittsburgh			1,560	1,499	1,772	1,620
Portland			2,082	1,711	1,940	1,758
St. Louis			1,509	1,659	1,790	1,730
San Francisco-Oakland			2,209	1,585	2,029	1,633
Washington, D. C.			1,254	1,390	1,552	1,525

[1]Wholesale price less transportation costs.

[2]The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

*Denotes consuming centers that received shipments, or would have received shipments from Kansas under the optimum situation.

APPENDIX TABLE 48.—Carlot Unloads of Kentucky Sweet Potatoes and Estimated Revenue Resulting from Actual and Optimum[1] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
	Carlot equivalents					
Atlanta						
Baltimore						
Birmingham						
Boston						
Chicago						
Cincinnati					2	
Cleveland						
Dallas-Ft. Worth						
Denver						
Detroit						
Kansas City						
Los Angeles						
Louisville						2
Minneapolis-St. Paul						
New Orleans						
New York-Newark						
Philadelphia						
Pittsburgh						
Portland						
St. Louis						
San Francisco-Oakland						
Washington, D. C.						
Total unloads					2	2
Net revenue (dollars)					3,736	3,590

[1]The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

APPENDIX TABLE 49.—Estimated Net Prices[1] Per Carload of Sweet Potatoes to Kentucky Shippers Resulting from Actual and Optimum[2] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
	Dollars					
Atlanta					1,580	1,700
Baltimore					1,150	1,454
Birmingham					1,305	1,699
Boston					1,295	1,557
Chicago					1,903	1,755
Cincinnati					1,868*	1,776
Cleveland					1,923	1,740
Dallas-Ft. Worth					1,443	1,614
Denver					1,860	1,678
Detroit					1,958	1,757
Kansas City					1,992	1,752
Los Angeles					1,673	1,621
Louisville					1,855	1,795*
Minneapolis-St. Paul					2,267	1,747
New Orleans					1,508	1,576
New York-Newark					1,577	1,601
Philadelphia					1,325	1,570
Pittsburgh					1,842	1,690
Portland					1,820	1,638
St. Louis					1,825	1,765
San Francisco-Oakland					1,909	1,513
Washington, D. C.					1,632	1,605

[1]Wholesale price less transportation costs.

[2]The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

*Denotes consuming centers that received shipments, or would have received shipments from Kentucky under the optimum situation.

APPENDIX TABLE 50.—Carlot Unloads of Louisiana Sweet Potatoes and Estimated Revenue Resulting from Actual and Optimum[1] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Carlot equivalents			
Atlanta						
Baltimore			12		10	
Birmingham					2	8
Boston					2	
Chicago	43		552	282	356	438
Cincinnati	11		84		42	16
Cleveland	16		222		110	
Dallas-Ft.Worth						
Denver	6	127	60		6	44
Detroit	21		270		148	
Kansas City	9		84	126	22	38
Los Angeles		49		882		70
Louisville	7		48		28	16
Minneapolis-St. Paul	1		48	312	24	182
New Orleans	13		270	216	116	108
New York-Newark	13		36		28	
Philadelphia	6		12		4	
Pittsburgh	10		84		40	
Portland						
St. Louis	15		132	96	72	90
San Francisco-Oakland						
Washington, D. C.	5					
Total unloads	176	176	1,914	1,914	1,010	1,010
Net revenue (dollars)	350,568	428,511	2,996,460	3,052,224	1,781,374	1,673,558

[1] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

APPENDIX TABLE 51.—Estimated Net Prices[1] Per Carload of Sweet Potatoes to Louisiana Shippers Resulting from Actual and Optimum[2] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Dollars			
Atlanta	2,365	2,296	1,493	1,561	1,525	1,645
Baltimore	1,495	1,616	933*	1,206	1,060*	1,364
Birmingham	1,960	2,337	1,423	1,577	1,265*	1,659*
Boston	1,555	1,625	1,183	1,320	1,200*	1,462
Chicago	2,000*	2,287	1,578*	1,594*	1,803*	1,655*
Cincinnati	1,725*	2,243	1,495*	1,525	1,748*	1,656*
Cleveland	2,050*	2,172	1,620*	1,468	1,808*	1,625
Dallas-Ft.Worth	2,895	2,518	1,527	1,596	1,493	1,664
Denver	3,195*	2,435*	1,581*	1,588	1,835*	1,653*
Detroit	2,065*	2,194	1,679*	1,507	1,848*	1,647
Kansas City	2,095*	2,366	1,713*	1,592*	1,917*	1,677*
Los Angeles	2,265	2,434*	1,847	1,594*	1,703	1,651*
Louisville	2,286*	2,286	1,619*	1,559	1,740*	1,680*
Minneapolis-St. Paul	2,056*	2,072	1,921*	1,595*	2,172*	1,652*
New Orleans	1,915*	2,138	1,447*	1,602*	1,598*	1,666*
New York-Newark	1,510*	1,810	1,326*	1,362	1,482*	1,506
Philadelphia	1,540*	1,782	1,051*	1,344	1,240*	1,485
Pittsburgh	1,926*	2,109	1,500*	1,439	1,712*	1,560
Portland	2,370	2,272	1,937	1,566	1,795	1,613
St. Louis	1,861*	2,372	1,439*	1,589*	1,720*	1,660*
San Francisco-Oakland	2,940	2,401	2,124	1,500	1,944	1,548
Washington, D. C.	2,481*	2,056	1,249	1,385	1,547	1,520

[1] Wholesale price less transportation costs.

[2] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

*Denotes consuming centers that received shipments, or would have received shipments from Louisiana under the optimum situation.

APPENDIX TABLE 52.—Carlot Unloads of Maryland Sweet Potatoes and Estimated Revenue Resulting from Actual and Optimum[1] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Carlot equivalents			
Atlanta						
Baltimore	5		144		76	
Birmingham						
Boston	8		24		12	
Chicago		8				
Cincinnati			12		12	
Cleveland		3	30		10	
Dallas-Ft. Worth						
Denver						
Detroit		9				
Kansas City						
Los Angeles						
Louisville						
Minneapolis-St. Paul						
New Orleans						
New York-Newark	1		138	384	30	182
Philadelphia	3		66		16	
Pittsburgh	4		42	96	12	
Portland						
St. Louis		2			4	
San Francisco-Oakland						
Washington, D. C.	1		24		10	
Total unloads	22	22	480	480	182	182
Net revenue (dollars)	41,940	50,877	695,334	788,352	284,100	325,052

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[1] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

APPENDIX TABLE 53.—Estimated Net Prices[1] Per Carload of Sweet Potatoes to Maryland Shippers Resulting from Actual and Optimum[2] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Dollars			
Atlanta	2,330	2,261	1,458	1,526	1,490	1,610
Baltimore	1,755*	1,876	1,193*	1,466	1,320*	1,624
Birmingham	1,865	2,242	1,328	1,482	1,170	1,564
Boston	1,835*	1,905	1,463*	1,600	1,480*	1,742
Chicago	2,025	2,312*	1,603	1,619	1,828	1,680
Cincinnati	1,790	2,308	1,560*	1,590	1,813*	1,721
Cleveland	2,200	2,322*	1,770*	1,618	1,958*	1,775
Dallas-Ft. Worth	2,635	2,258	1,267	1,336	1,233	1,404
Denver	3,070	2,310	1,456	1,463	1,710	1,528
Detroit	2,180	2,309*	1,794	1,622	1,963	1,762
Kansas City	2,010	2,281	1,628	1,507	1,832	1,592
Los Angeles	2,050	2,219	1,632	1,379	1,488	1,436
Louisville	2,296	2,296	1,629	1,569	1,750	1,690
Minneapolis-St. Paul	2,051	2,067	1,916	1,590	2,167	1,647
New Orleans	1,660	1,883	1,192	1,347	1,343	1,411
New York-Newark	1,790*	2,090	1,606*	1,642*	1,762*	1,786*
Philadelphia	1,815*	2,057	1,326*	1,619	1,515*	1,760
Pittsburgh	2,131*	2,314	1,705*	1,644*	1,917*	1,765
Portland	2,245	2,147	1,812	1,441	1,670	1,488
St. Louis	1,806	2,317*	1,384	1,534	1,665*	1,605
San Francisco-Oakland	2,750	2,211	1,934	1,310	1,754	1,358
Washington, D. C.	2,726*	2,301	1,494*	1,630	1,792*	1,765

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[1] Wholesale price less transportation costs.

[2] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

*Denotes consuming centers that received shipments, or would have received shipments from Maryland under the optimum situation.

APPENDIX TABLE 54.—Carlot Unloads of Mississippi Sweet Potatoes and Estimated Revenue Resulting from Actual and Optimum[1] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Carlot equivalents			
Atlanta	2		24		2	
Baltimore						
Birmingham	9		12		2	
Boston						
Chicago			12		2	
Cincinnati	4		6			
Cleveland	1		6		2	
Dallas-Ft. Worth						
Denver			6			
Detroit			6			
Kansas City					2	
Los Angeles						
Louisville			6		2	
Minneapolis-St. Paul			6			
New Orleans						
New York-Newark						
Philadelphia						
Pittsburgh						
Portland		19		102		18
St. Louis	3		18		6	
San Francisco-Oakland						
Washington, D. C.						
Total unloads	19	19	102	102	18	18
Net revenue (dollars)	38,223	52,763	163,236	211,242	31,526	38,124

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[1] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

APPENDIX TABLE 55.—Estimated Net Prices[1] Per Carload of Sweet Potatoes to Mississippi Shippers Resulting from Actual and Optimum[2] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Dollars			
Atlanta	2,430*	2,361	1,558*	1,626	1,590*	1,710
Baltimore	1,560	1,681	998	1,271	1,125	1,429
Birmingham	2,030*	2,407	1,493*	1,647	1,335*	1,729
Boston	1,625	1,695	1,253	1,390	1,270	1,532
Chicago	2,050	2,337	1,628*	1,644	1,853*	1,705
Cincinnati	1,805*	2,323	1,575*	1,605	1,828	1,736
Cleveland	2,125*	2,247	1,695*	1,543	1,883*	1,700
Dallas-Ft. Worth	2,865	2,488	1,497	1,566	1,463	1,634
Denver	3,185	2,425	1,571*	1,578	1,825	1,643
Detroit	2,135	2,264	1,749*	1,577	1,918	1,717
Kansas City	2,140	2,411	1,758	1,637	1,962*	1,722
Los Angeles	2,240	2,409	1,822	1,569	1,678	1,626
Louisville	2,361	2,361	1,694*	1,634	1,815*	1,755
Minneapolis-St. Paul	2,101	2,117	1,966*	1,640	2,217	1,697
New Orleans	1,865	2,088	1,397	1,552	1,548	1,616
New York-Newark	1,580	1,880	1,396	1,432	1,552	1,576
Philadelphia	1,600	1,842	1,111	1,404	1,300	1,545
Pittsburgh	2,016	2,199	1,590	1,529	1,802	1,650
Portland	2,875	2,777*	2,442	2,071*	2,300	2,118*
St. Louis	1,916*	2,427	1,494*	1,644	1,775*	1,715
San Francisco-Oakland	2,910	2,371	2,094	1,470	1,914	1,518
Washington, D. C.	2,546	2,121	1,314	1,450	1,612	1,585

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[1] Wholesale price less transportation costs.

[2] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

*Denotes consuming centers that received shipments, or would have received shipments from Mississippi under the optimum situation.

APPENDIX TABLE 56.—Carlot Unloads of Missouri Sweet Potatoes and Estimated Revenue Resulting from Actual and Optimum[1] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Carlot equivalents			
Atlanta						
Baltimore						
Birmingham						
Boston						
Chicago						
Cincinnati						
Cleveland						
Dallas-Ft. Worth						
Denver						
Detroit						
Kansas City						
Los Angeles						
Louisville						
Minneapolis-St. Paul						
New Orleans						
New York-Newark						
Philadelphia						
Pittsburgh						
Portland						
St. Louis	3	3	66	66	20	20
San Francisco-Oakland						
Washington, D. C.						
Total unloads	3	3	66	66	20	20
Net revenue (dollars)	6,033	7,566	104,874	114,774	37,400	36,200

[1]The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

APPENDIX TABLE 57.—Estimated Net Prices[1] Per Carload of Sweet Potatoes to Missouri Shippers Resulting from Actual and Optimum[2] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Dollars			
Atlanta	2,375	2,306	1,503	1,571	1,535	1,655
Baltimore	1,590	1,711	1,028	1,301	1,155	1,459
Birmingham	1,945	2,322	1,408	1,562	1,250	1,644
Boston	1,660	1,730	1,288	1,425	1,305	1,567
Chicago	2,135	2,422	1,713	1,729	1,938	1,790
Cincinnati	1,845	2,363	1,615	1,645	1,868	1,776
Cleveland	2,180	2,302	1,750	1,598	1,938	1,755
Dallas-Ft. Worth	2,830	2,453	1,462	1,531	1,428	1,599
Denver	3,270	2,510	1,656	1,663	1,910	1,728
Detroit	2,200	2,329	1,814	1,642	1,983	1,782
Kansas City	2,215	2,486	1,833	1,712	2,037	1,797
Los Angeles	2,255	2,424	1,837	1,584	1,693	1,641
Louisville	2,396	2,396	1,729	1,669	1,850	1,790
Minneapolis-St. Paul	2,191	2,207	2,056	1,730	2,307	1,787
New Orleans	1,780	2,003	1,312	1,467	1,463	1,531
New York-Newark	1,615	1,915	1,431	1,467	1,587	1,611
Philadelphia	1,640	1,882	1,151	1,444	1,340	1,585
Pittsburgh	2,066	2,249	1,640	1,579	1,852	1,700
Portland	2,445	2,347	2,012	1,641	1,870	1,688
St. Louis	2,011*	2,522*	1,589*	1,739*	1,870*	1,810*
San Francisco-Oakland	2,950	2,411	2,134	1,510	1,954	1,558
Washington, D. C.	2,566	2,141	1,334	1,470	1,632	1,605

[1]Wholesale price less transportation costs.

[2]The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

*Denotes consuming centers that received shipments, or would have received shipments from Missouri under the optimum situation.

APPENDIX TABLE 58.—Carlot Unloads of New Jersey Sweet Potatoes and Estimated Revenue Resulting from Actual and Optimum[1] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Carlot equivalents			
Atlanta			12			
Baltimore			144		36	
Birmingham						
Boston			192	36	128	14
Chicago			18	90	14	
Cincinnati			6		2	
Cleveland			24	324	18	156
Dallas-Ft. Worth						
Denver						
Detroit		1		288	2	54
Kansas City						
Los Angeles						
Louisville						
Minneapolis-St. Paul			6		14	
New Orleans						
New York-Newark	1		426	168	292	242
Philadelphia			426	306	224	212
Pittsburgh			150	234	88	160
Portland						
St. Louis						
San Francisco-Oakland						
Washington, D. C.			48	6	20	
Total unloads	1	1	1,452	1,452	838	838
Net revenue (dollars)	1,770	2,314	2,137,968	2,364,144	1,393,146	1,482,588

[1] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

APPENDIX TABLE 59.—Estimated Net Prices[1] Per Carload of Sweet Potatoes to New Jersey Shippers Resulting from Actual and Optimum[2] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Dollars			
Atlanta	2,325	2,256	1,453*	1,521	1,485	1,605
Baltimore	1,755	1,876	1,193*	1,466	1,320*	1,624
Birmingham	1,860	2,237	1,323	1,477	1,165	1,559
Boston	1,860	1,930	1,488*	1,625*	1,505*	1,767
Chicago	2,030	2,317	1,608*	1,624*	1,833*	1,685
Cincinnati	1,790	2,308	1,560*	1,590	1,813*	1,721
Cleveland	2,205	2,327	1,775*	1,623*	1,963*	1,780
Dallas-Ft. Worth	2,630	2,253	1,262	1,331	1,228	1,399
Denver	3,070	2,310	1,456	1,463	1,710	1,528
Detroit	2,185	2,314*	1,799	1,627*	1,968*	1,767*
Kansas City	2,010	2,281	1,628	1,507	1,832	1,592
Los Angeles	2,040	2,209	1,622	1,369	1,478	1,426
Louisville	2,296	2,296	1,629	1,569	1,750	1,690
Minneapolis-St. Paul	2,056	2,072	1,921*	1,595	2,172*	1,652
New Orleans	1,655	1,878	1,187	1,342	1,338	1,406
New York-Newark	1,770*	2,070	1,586*	1,622*	1,742*	1,766*
Philadelphia	1,820	2,062	1,331*	1,624*	1,520*	1,765
Pittsburgh	2,136	2,319	1,710*	1,649*	1,922*	1,770*
Portland	2,250	2,152	1,817	1,446	1,675	1,493
St. Louis	1,806	2,317	1,384	1,534	1,665	1,605
San Francisco-Oakland	2,755	2,216	1,939	1,315	1,759	1,363
Washington, D. C.	2,721	2,296	1,489*	1,625*	1,787*	1,760

[1] Wholesale price less transportation costs.

[2] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

*Denotes consuming centers that received shipments, or would have received shipments from New Jersey under the optimum situation.

APPENDIX TABLE 60.—Carlot Unloads of New Mexico Sweet Potatoes and Estimated Revenue Resulting from Actual and Optimum[1] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Carlot equivalents			
Atlanta						
Baltimore						
Birmingham						
Boston						
Chicago						
Cincinnati						
Cleveland						
Dallas-Ft. Worth	1		30		14	
Denver			6			
Detroit						
Kansas City						
Los Angeles		1		36		14
Louisville						
Minneapolis-St. Paul						
New Orleans						
New York-Newark						
Philadelphia						
Pittsburgh						
Portland						
St. Louis						
San Francisco-Oakland						
Washington, D. C.						
Total unloads	1	1	36	36	14	14
Net revenue (dollars)	2,875	2,614	55,656	63,864	20,622	25,634

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[1] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

APPENDIX TABLE 61.—Estimated Net Prices[1] Per Carload of Sweet Potatoes to New Mexico Shippers Resulting from Actual and Optimum[2] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Dollars			
Atlanta	2,210	2,141	1,338	1,406	1,370	1,490
Baltimore	1,385	1,506	823	1,096	950	1,254
Birmingham	1,810	2,187	1,273	1,427	1,115	1,509
Boston	1,455	1,525	1,083	1,220	1,100	1,362
Chicago	1,925	2,212	1,503	1,519	1,728	1,580
Cincinnati	1,640	2,158	1,410	1,440	1,663	1,571
Cleveland	1,970	2,092	1,540	1,388	1,728	1,545
Dallas-Ft. Worth	2,875*	2,498	1,507*	1,576	1,473*	1,644
Denver	3,355	2,595	1,741*	1,748	1,995	1,813
Detroit	1,990	2,119	1,604	1,432	1,773	1,572
Kansas City	2,110	2,381	1,728	1,607	1,932	1,692
Los Angeles	2,445	2,614*	2,027	1,774*	1,883	1,831*
Louisville	2,176	2,176	1,509	1,449	1,630	1,570
Minneapolis-St. Paul	2,056	2,072	1,921	1,595	2,172	1,652
New Orleans	1,725	1,948	1,257	1,412	1,408	1,476
New York-Newark	1,410	1,710	1,226	1,262	1,382	1,406
Philadelphia	1,430	1,672	941	1,234	1,130	1,375
Pittsburgh	1,856	2,039	1,430	1,369	1,642	1,490
Portland	2,555	2,457	2,122	1,751	1,980	1,798
St. Louis	1,806	2,317	1,384	1,534	1,665	1,605
San Francisco-Oakland	3,105	2,566	2,289	1,665	2,109	1,713
Washington, D. C.	2,361	1,936	1,129	1,265	1,427	1,400

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[1] Wholesale price less transportation costs.

[2] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

*Denotes consuming centers that received shipments, or would have received shipments from New Mexico under the optimum situation.

APPENDIX TABLE 62.—Carlot Unloads of North Carolina Sweet Potatoes and Estimated Revenue Resulting from Actual and Optimum[1] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Carlot equivalents			
Atlanta		11	24	126	16	
Baltimore			12		2	
Birmingham						
Boston			6		4	
Chicago				240	2	
Cincinnati			18	180	4	88
Cleveland					2	6
Dallas-Ft. Worth						
Denver						
Detroit			36	102	8	134
Kansas City						
Los Angeles						
Louisville		3		78	2	
Minneapolis-St. Paul						
New Orleans						
New York-Newark	7		420		208	
Philadelphia	3		102		40	
Pittsburgh	1		6		2	4
Portland						
St. Louis						
San Francisco-Oakland						
Washington, D. C.	3		102		42	100
Total unloads	14	14	726	726	332	332
Net revenue (dollars)	27,429	32,729	1,082,490	1,162,932	554,212	574,946

[1]The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

APPENDIX TABLE 63.—Estimated Net Prices[1] Per Carload of Sweet Potatoes to North Carolina Shippers Resulting from Actual and Optimum[2] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Dollars			
Atlanta	2,410	2,341*	1,538*	1,606*	1,570*	1,690
Baltimore	1,705	1,826	1,143*	1,416	1,270*	1,574
Birmingham	1,930	2,307	1,393	1,547	1,235	1,629
Boston	1,765	1,835	1,393*	1,530	1,410*	1,672
Chicago	2,010	2,297	1,588	1,604*	1,813*	1,665
Cincinnati	1,800	2,318	1,570*	1,600*	1,823*	1,731*
Cleveland	2,165	2,287	1,735	1,583	1,923*	1,740*
Dallas-Ft. Worth	2,695	2,318	1,327	1,396	1,293	1,464
Denver	3,065	2,305	1,451	1,458	1,705	1,523
Detroit	2,155	2,284	1,769*	1,597*	1,938*	1,737*
Kansas City	2,020	2,291	1,638	1,517	1,842	1,602
Los Angeles	2,065	2,234	1,647	1,394	1,503	1,451
Louisville	2,326	2,326*	1,659	1,599*	1,780*	1,720
Minneapolis-St. Paul	2,036	2,052	1,901	1,575	2,152	1,632
New Orleans	1,715	1,938	1,247	1,402	1,398	1,466
New York-Newark	1,720*	2,020	1,536*	1,572	1,692*	1,716
Philadelphia	1,745*	1,987	1,256*	1,549	1,445*	1,690
Pittsburgh	2,096*	2,279	1,670*	1,609	1,882*	1,730*
Portland	2,240	2,142	1,807	1,436	1,665	1,483
St. Louis	1,821	2,332	1,399	1,549	1,680	1,620
San Francisco-Oakland	2,745	2,206	1,929	1,305	1,749	1,353
Washington, D. C.	2,686*	2,261	1,454*	1,590	1,752*	1,725*

[1]Wholesale price less transportation costs.

[2]The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

*Denotes consuming centers that received shipments, or would have received shipments from North Carolina under the optimum situation.

APPENDIX TABLE 64.—Carlot Unloads of South Carolina Sweet Potatoes and Estimated Revenue Resulting from Actual and Optimum[1] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Carlot equivalents			
Atlanta	4	5	30	54	14	20
Baltimore			6			
Birmingham						
Boston						
Chicago						
Cincinnati						
Cleveland						
Dallas-Ft. Worth						
Denver						
Detroit						
Kansas City						
Los Angeles						
Louisville						8
Minneapolis-St. Paul						
New Orleans						
New York-Newark			6		10	
Philadelphia			6		2	
Pittsburgh						
Portland						
St. Louis						
San Francisco-Oakland						
Washington, D. C.	1		6		2	
Total unloads	5	5	54	54	28	28
Net revenue (dollars)	12,391	11,830	78,204	88,074	45,104	48,060

[1] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

APPENDIX TABLE 65.—Estimated Net Prices[1] Per Carload of Sweet Potatoes to South Carolina Shippers Resulting from Actual and Optimum[2] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Dollars			
Atlanta	2,435*	2,366*	1,563*	1,631*	1,595*	1,715*
Baltimore	1,665	1,786	1,103*	1,376	1,230	1,534
Birmingham	1,955	2,332	1,418	1,572	1,260	1,654
Boston	1,730	1,800	1,358	1,495	1,375	1,637
Chicago	2,005	2,292	1,583	1,599	1,808	1,660
Cincinnati	1,790	2,308	1,560	1,590	1,813	1,721
Cleveland	2,125	2,247	1,695	1,543	1,883	1,700
Dallas-Ft. Worth	2,720	2,343	1,352	1,421	1,318	1,489
Denver	3,070	2,310	1,456	1,463	1,710	1,528
Detroit	2,120	2,249	1,734	1,562	1,903	1,702
Kansas City	2,025	2,296	1,643	1,522	1,847	1,607
Los Angeles	2,090	2,259	1,672	1,419	1,528	1,476
Louisville	2,326	2,326	1,659	1,599	1,780	1,720*
Minneapolis-St. Paul	2,031	2,047	1,896	1,570	2,147	1,627
New Orleans	1,760	1,983	1,292	1,447	1,443	1,511
New York-Newark	1,685	1,985	1,501*	1,537	1,657*	1,681
Philadelphia	1,685	1,927	1,196*	1,489	1,385*	1,630
Pittsburgh	2,056	2,239	1,630	1,569	1,842	1,690
Portland	2,245	2,147	1,812	1,441	1,670	1,488
St. Louis	1,826	2,337	1,404	1,554	1,685	1,625
San Francisco-Oakland	2,765	2,226	1,949	1,325	1,769	1,373
Washington, D. C.	2,651*	2,226	1,419*	1,555	1,717*	1,690

[1] Wholesale price less transportation costs.

[2] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

*Denotes consuming centers that received shipments, or would have received shipments from South Carolina under the optimum situation.

APPENDIX TABLE 66.—Carlot Unloads of Tennessee Sweet Potatoes and Estimated Revenue Resulting from Actual and Optimum[1] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Carlot equivalents			
Atlanta			12		4	
Baltimore						
Birmingham						
Boston						
Chicago	2		12	6	2	
Cincinnati	1		6		2	
Cleveland						
Dallas-Ft. Worth		3				
Denver		1				
Detroit						
Kansas City						
Los Angeles						
Louisville			6		2	12
Minneapolis-St. Paul						
New Orleans						
New York-Newark						
Philadelphia						
Pittsburgh						
Portland						
St. Louis	1		6	36	2	
San Francisco-Oakland						
Washington, D. C.						
Total unloads	4	4	42	42	12	12
Net revenue (dollars)	8,011	9,864	68,070	71,148	21,222	21,540

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[1] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

APPENDIX TABLE 67.—Estimated Net Prices[1] Per Carload of Sweet Potatoes to Tennessee Shippers Resulting from Actual and Optimum[2] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Dollars			
Atlanta	2,420	2,351	1,548*	1,616	1,580*	1,700
Baltimore	1,585	1,706	1,023	1,296	1,150	1,454
Birmingham	2,000	2,377	1,463	1,617	1,305	1,699
Boston	1,650	1,720	1,278	1,415	1,295	1,557
Chicago	2,100*	2,387	1,678*	1,694*	1,903*	1,755
Cincinnati	1,845*	2,363	1,615*	1,645	1,868*	1,776
Cleveland	2,165	2,287	1,735	1,583	1,923	1,740
Dallas-Ft. Worth	2,845	2,468*	1,477	1,546	1,443	1,614
Denver	3,220	2,460*	1,606	1,613	1,860	1,678
Detroit	2,175	2,304	1,789	1,617	1,958	1,757
Kansas City	2,170	2,441	1,788	1,667	1,992	1,752
Los Angeles	2,235	2,404	1,817	1,564	1,673	1,621
Louisville	2,401	2,401	1,734*	1,674	1,855*	1,795*
Minneapolis-St. Paul	2,151	2,167	2,016	1,690	2,267	1,747
New Orleans	1,825	2,048	1,357	1,512	1,508	1,576
New York-Newark	1,605	1,905	1,421	1,457	1,577	1,601
Philadelphia	1,625	1,867	1,136	1,429	1,325	1,570
Pittsburgh	2,056	2,239	1,630	1,569	1,842	1,690
Portland	2,395	2,297	1,962	1,591	1,820	1,638
St. Louis	1,966*	2,477	1,544*	1,694*	1,825*	1,765
San Francisco-Oakland	2,905	2,366	2,089	1,465	1,909	1,513
Washington, D. C.	2,566	2,141	1,334	1,470	1,632	1,605

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[1] Wholesale price less transportation costs.

[2] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

*Denotes consuming centers that received shipments, or would have received shipments from Tennessee under the optimum situation.

APPENDIX TABLE 68.—Carlot Unloads of Texas Sweet Potatoes and Estimated Revenue Resulting from Actual and Optimum[1] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Carlot equivalents			
Atlanta			54		8	
Baltimore						
Birmingham			36		16	
Boston						
Chicago			48		24	
Cincinnati	1		24		6	
Cleveland	1		6		4	
Dallas-Ft. Worth	14	18	300	306	130	124
Denver			42	114	24	72
Detroit					2	
Kansas City			6		6	16
Los Angeles				120		20
Louisville						
Minneapolis-St. Paul	1		6		6	
New Orleans						
New York-Newark						
Philadelphia					2	
Pittsburgh					4	
Portland	1		12			
St. Louis			6			
San Francisco-Oakland						
Washington, D. C.						
Total unloads	18	18	540	540	232	232
Net revenue (dollars)	49,641	46,404	850,068	894,258	377,950	399,424

[1] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

APPENDIX TABLE 69.—Estimated Net Prices[1] Per Carload of Sweet Potatoes to Texas Shippers Resulting from Actual and Optimum[2] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Dollars			
Atlanta	2,335	2,266	1,463*	1,531	1,495*	1,615
Baltimore	1,465	1,586	903	1,176	1,030	1,334
Birmingham	1,935	2,312	1,398*	1,552	1,240*	1,634
Boston	1,340	1,410	968	1,105	985	1,247
Chicago	1,990	2,277	1,568*	1,584	1,793*	1,645
Cincinnati	1,720*	2,238	1,490*	1,520	1,743*	1,651
Cleveland	2,040*	2,162	1,610*	1,458	1,798*	1,615
Dallas-Ft. Worth	2,955*	2,578*	1,587*	1,656*	1,533*	1,724*
Denver	3,260	2,500	1,646*	1,653*	1,900*	1,718*
Detroit	2,060	2,189	1,674	1,502	1,843*	1,642
Kansas City	2,145	2,416	1,763*	1,642	1,967*	1,727*
Los Angeles	2,330	2,499	1,912	1,659*	1,768	1,716*
Louisville	2,276	2,276	1,609	1,549	1,730	1,670
Minneapolis-St. Paul	2,091*	2,107	1,956*	1,630	2,207*	1,687
New Orleans	1,850	2,073	1,382	1,537	1,533	1,601
New York-Newark	1,485	1,785	1,301	1,337	1,457	1,481
Philadelphia	1,510	1,752	1,021	1,314	1,210*	1,455
Pittsburgh	1,921	2,104	1,495	1,434	1,707*	1,555
Portland	2,420*	2,322	1,987*	1,616	1,845	1,663
St. Louis	1,866	2,377	1,444*	1,594	1,725	1,665
San Francisco-Oakland	3,000	2,461	2,184	1,560	2,004	1,608
Washington, D. C.	2,451	2,026	1,219	1,355	1,517	1,490

[1] Wholesale price less transportation costs.

[2] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

*Denotes consuming centers that received shipments, or would have received shipments from Texas under the optimum situation.

APPENDIX TABLE 70.—Carlot Unloads of Virginia Sweet Potatoes and Estimated Revenue Resulting from Actual and Optimum[1] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Carlot equivalents			
Atlanta	4		60		24	
Baltimore	26		96		32	
Birmingham						
Boston	10		24		2	
Chicago						
Cincinnati	3	3	6			
Cleveland		11	6		2	
Dallas-Ft. Worth						
Denver						
Detroit		2	6			
Kansas City						
Los Angeles						
Louisville		4				
Minneapolis-St. Paul						
New Orleans						
New York-Newark	55		228	642	106	238
Philadelphia	50		144		50	
Pittsburgh	12	21	36		8	
Portland					2	
St. Louis						
San Francisco-Oakland						
Washington, D. C.	5	124	36		12	
Total unloads	165	165	642	642	238	238
Net revenue (dollars)	304,847	378,376	933,210	1,044,534	385,038	421,498

[1] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

APPENDIX TABLE 71.—Estimated Net Prices[1] Per Carload of Sweet Potatoes to Virginia Shippers Resulting from Actual and Optimum[2] Distributions, by Consuming Centers and Marketing Periods, 1958-59 Crop Season

Consuming center	Marketing periods					
	1		2		3	
	Actual	Optimum	Actual	Optimum	Actual	Optimum
			Dollars			
Atlanta	2,355*	2,286	1,483*	1,551	1,515*	1,635
Baltimore	1,740*	1,861	1,178*	1,451	1,305*	1,609
Birmingham	1,875	2,252	1,338	1,492	1,180	1,574
Boston	1,825*	1,895	1,453*	1,590	1,470*	1,732
Chicago	2,005	2,292	1,583	1,599	1,808	1,660
Cincinnati	1,780*	2,298*	1,550*	1,580	1,803	1,711
Cleveland	2,185	2,307*	1,755*	1,603	1,943*	1,760
Dallas-Ft. Worth	2,645	2,268	1,277	1,346	1,243	1,414
Denver	3,055	2,295	1,441	1,448	1,695	1,513
Detroit	2,160	2,289*	1,774*	1,602	1,943	1,742
Kansas City	1,985	2,256	1,603	1,482	1,807	1,567
Los Angeles	2,035	2,204	1,617	1,364	1,473	1,421
Louisville	2,291	2,291*	1,624	1,564	1,745	1,685
Minneapolis-St. Paul	2,031	2,047	1,896	1,570	2,147	1,627
New Orleans	1,680	1,903	1,212	1,367	1,363	1,431
New York-Newark	1,775*	2,075	1,591*	1,627*	1,747*	1,771*
Philadelphia	1,800*	2,042	1,311*	1,604	1,500*	1,745
Pittsburgh	2,116*	2,299*	1,690*	1,629	1,902*	1,750
Portland	2,230	2,132	1,797	1,426	1,655*	1,473
St. Louis	1,786	2,297	1,364	1,514	1,645	1,585
San Francisco-Oakland	2,735	2,196	1,919	1,295	1,739	1,343
Washington, D. C.	2,716*	2,291*	1,484*	1,620	1,782*	1,755

[1] Wholesale price less transportation costs.

[2] The optimum for the specified producing area is shown for the situation in which all producing areas move toward optimum shipping patterns.

*Denotes consuming centers that received shipments, or would have received shipments from Virginia under the optimum situation.

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Foliar Analysis of Sugar Cane in Louisiana

LARON E. GOLDEN

RAY RICAUD

Louisiana State University and
Agricultural and Mechanical College
Agricultural Experiment Station
Doyle Chambers, Director

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Foliar Analysis of Sugar Cane in Louisiana

Laron E. Golden and Ray Ricaud

Foliar analysis of sugar cane is being used in many areas to obtain additional knowledge about the composition of the plant, and other growth production factors, and how they are interrelated (*4, 5, 17, 25, 31*). Results of analysis of different plant parts are being used as a guide for fertilization of sugar cane in many countries (*3, 4, 11, 12, 22, 27, 32*).

The nutrient contents of sugar cane have been found to differ as a result of differences in fertilizer treatments (*2, 6, 7, 14, 15, 21, 22, 23, 24*), soils (*3, 8, 10, 20*), varieties (*8, 18, 20, 21, 33*), climate (*1, 12, 30*), age (*1, 12, 28, 30*), culture (*33*), age class (plant or stubble cane) (*8*) and competition from weeds (*20*). Evans *et al.* (*16*) reported that foliar analysis has been more successful with sugar cane than with many other crops due to rate and quantity of dry matter production and to the fact that there is a high probability that a suboptimal level of one or more nutrient elements may limit production of sugar cane during periods of growth when climatic factors are not limiting. When the agronomic and economic conditions provide justification, sufficient foliar diagnosis may be accomplished to determine the periods during which indicator plant parts of sugar cane will reflect sufficient differences in nutrient composition, as a result of an insufficient supply from soils and fertilizers, to warrant use of such differences as a basis for fertilizer recommendations.

Foliar analysis of sugar cane, or "crop logging" as it is termed by Clements (*11, 12*), has been developed to a high degree in Hawaii (*2, 6, 7, 11, 12, 23*).

Byrnside and Sturgis (*10*) found a high correlation between soil test values for available phosphorus and yield responses of sugar cane to fertilizer phosphorus in Louisiana. Ricaud (*29*) found soil test values for available potassium to be significantly correlated with yield responses of the crop to fertilizer potassium in Louisiana. Unpublished work by the authors shows a positive but statistically insignificant association between total soil nitrogen in soils on which sugar cane is grown in Louisiana and yield responses to fertilizer nitrogen.

Sturgis (*34*) reported that sugar cane removed 4,288 tons of N, 2,680 tons of P_20_5 and 11,936 tons of K_20 from soils in Louisiana in 1959. Additional N and K_20 were lost in burning sugar cane trash. This high utilization of plant nutrients by sugar cane points up the necessity for using all means available and that may be developed to improve the efficiency of the use of plant nutrients.

Results from approximately 200 field experiments during 25 years of research with fertilizers for sugar cane in Louisiana have been used as a basis for making recommendations for use of fertilizers in Louisiana.

A need exists, however, for additional techniques which will further minimize the chances for error when recommendations are made.

Experimental

Soil and Plant Material

General soil samples were taken for analysis from all fields where leaf-blade samples were obtained in the study. Leaf-blade samples were taken from selected varieties at one variety test site on a Recent Mississippi alluvial soil and one variety test site on a Pleistocene terrace soil three times approximately six weeks apart during each year 1960, 1961 and 1962. Four of the most common varieties presently used in Louisiana, C. P. 44-101, C. P. 48-103, C. P. 52-68 and N. Co. 310, were chosen for sampling. The variety C. P. 36-105 was sampled and analyzed in 1960 only. Both plant cane and first stubble cane were sampled at each of the two locations each year at the three sampling dates.

A total of 13 fertilizer test sites were chosen during the years 1959, 1960, 1961 and 1962 on Recent Mississippi alluvial soils and Recent Mississippi terrace soils from which leaf-blade samples were taken three times each year approximately six weeks apart beginning in mid-June. At each fertilizer test site, samples were obtained from 13 fertilizer treatments. These included the 0-0-0 (check) treatment and 12 treatments comprising a complete factorial experiment of three levels of N, two of P_20_5 and two of K_20 in all possible combinations. The levels of nutrients used in fertilizer treatments are shown in the tables under Results and Discussion.

Leaf-blade samples were composed of 18 leaf blades from each treatment sampled. The fourth unfolded leaf down from the top, or "Kuijper" Leaf No. 4 (*35*), was chosen in each case.

Soil and Plant Analysis Procedures

Soil samples were composited, air-dried and passed through a 2 mm. sieve. Leaf-blade samples were dried in a forced-air oven at 60° C, ground to pass 1 mm. openings and dried again in a convection oven at 60° C. Nitrogen in the soil samples and plant samples was determined by the modified Kjeldahl method. Carbon in soils was determined by the dry combustion method, and organic matter content was calculated by multiplying per cent carbon by 1.724. Soil pH was determined by use of a Beckman Zeromatic pH meter. The Beckman Model DU spectrophotometer, with flame attachment and photomultiplier assembly, was used to determine K, Ca and Mg in the soil samples and K in plant samples. The P in soil and in plant samples was determined by the chlorostannous-reduced molybdophosphoric blue color method in hydrochloric acid system (*26*). For the determination of available P, K, Ca and Mg all extractions were accomplished at 25° C. (*19*).

Results and Discussion

General

Table 1 contains results of chemical analysis of soils used in the study. Some of the contents of the table are discussed concurrent with discussions relative to leaf-blade data reported in Tables 3-13.

The results obtained in Louisiana, shown in Table 2, are simple averages of all original data used in preparation of material reported in Tables 3-14. Samuels *et al.* (*31*) noted that very little difference existed in nutrient content of the leaf blades when the Hawaiian or British Guiana analytical methods were used. They state that the major difference in the Puerto Rican method from that of British Guiana and Hawaii is the fact that the midrib is included for analysis in Puerto Rico. The entire leaf blade including midrib, was used in samples collected in Louisiana, whereas, in Puerto Rico, leaf blades were cut into 2 or 3-inch sections, and a section was taken from the basal, middle and tip portion of each leaf blade. With the exception of K, the Louisiana and Puerto Rico data differ very little when it is considered that sugar cane in Louisiana may not be as far advanced physiologically at three months of age as that in Puerto Rico due to differences in growth as influenced by temperature and other environmental differences. Even though no special effort was made to select sites in Louisiana for study which were low in available soil K, the results were essentially the same. All except two of the available K values shown in Table 1 are considered to be "low" for sugar cane production in Louisiana. Fertilizer K is recommended for sugar cane in Louisiana when soil test values are "low."

Variety Study

Tables 3 and 4 contain experimental data which included varieties as variables but did not include fertilizer nutrients as variables. An analysis of variance of the data shown in Table 3 revealed no statistically significant differences from N, P and K contents of sugar cane leaves among years of study nor between soil types. Table 4 shows significant F values obtained in the analysis. The N content, as an average of the other variables in the study (year, soil type, variety and sampling time) was significantly lower in first stubble cane leaves than in plant cane leaves. The differences in P and K contents due to plant age, however, were not significant.

Varieties were found to have highly significant differences in N and P contents of leaves and significant differences in K content. The N, P and K contents of leaves of N. Co. 310 were higher than the N, P and K contents of any other variety. The variety N. Co. 310 has been reported (*21, 22*) as generally requiring more nutrients per ton of cane produced than other commercial varieties grown in Louisiana. The N and P contents of leaves were influenced to a highly significant degree by time

TABLE 1.—Results of Chemical Analysis of Soils

Location	Soil Type	Years of Experiment	Re-action pH	Organic Matter	Total N	Avail-able P	Avail-able K	Avail-able Ca	Avail-able Mg
				%	%	ppm	ppm	ppm	ppm
Cinclare	Mhoon sil	1960, 1961, 1962	6.2	0.78	0.042	221	63	1426	244
Young's Industries	Richland sil	1960, 1961, 1962	4.9	1.75	0.089	19	47	102	81
Smithfield	Commerce sil	1959, 1960	7.5	1.30	0.067	297	85	2404	623
Edgefield	Yahola vfsl	1959	8.4	0.81	0.041	318	92	5649	1215
Alice "B"	Jeanerette sil	1959, 1960	7.3	2.23	0.114	136	94	3714	765
O'Neil	Baldwin sicl	1959, 1960	4.8	2.28	0.125	30	155	1834	649
Little Texas	Mhoon sil	1960, 1961	6.7	1.38	0.068	216	78	1800	495
Alice "B"	Cypremort sil	1961	4.9	1.02	0.062	31	47	661	171
Alma	Commerce sil	1962	5.6	1.18	0.064	237	92	1174	331
Point Farm	Sharkey c	1962	6.6	3.66	0.175	362	311	5805	1565
Alice "B"	Baldwin sil	1962	7.1	1.55	0.071	82	66	3228	598

TABLE 2.—A Comparison of the Nutrient Composition of Sugar Cane Leaves When Using Different Leaf-sampling Methods[1]

Origin of method	Age when sampled	Leaf-Blade Kuijper number	Nutrient content of leaf blades on a dry weight basis for N	P	K
	Months		%	%	%
British Guiana	3-5	1	2.22	0.23	1.79
Hawaii	3-5	1-4	2.16	0.22	1.77
Puerto Rico	3-5	2-4	1.74	0.20	1.89
Puerto Rico	3	4	1.58	0.15	1.36
Louisiana	3	4	1.77	0.188	1.13
Louisiana	4½	4	1.45	0.160	1.15
Louisiana	6	4	1.36	0.149	1.17

[1] Data shown in this table for locations other than Louisiana were determined by Samuels et al. (*31*).

of sampling. The K content of leaves was not significantly influenced by time of sampling. Analysis of nutrient-content data obtained in 1960 only for the variety C. P. 36-105 showed N, P and K contents to differ very little from comparable data obtained from the varieties C. P. 44-101 and C. P. 52-68.

In Table 4, it may be noted that interactions between soil type and time of sampling were found for all three nutrients studied. A significant interaction of age and date of sampling on leaf-K content was noted, and highly significant interactions of varieties and time of sampling were reflected in leaf-N and leaf-P contents. A significant interaction of soil type, age and time of sampling on leaf-P content was found. The

TABLE 3.—Effect of Year, Soil Type, Age of Cane, Variety, and Date of Sampling on Nutrient Contents of Sugar Cane Leaves

Variable		Nutrient Contents N	P	K
		%	%	%
Year:	1960	1.54	0.159	1.22
	1961	1.53	0.152	1.30
	1962	1.45	0.159	1.10
Soil type:	Mhoon sil	1.46	0.160	1.19
	Richland sil	1.55	0.154	1.22
Age:	Plant	1.54	0.155	1.25
	1st stubble	1.47	0.159	1.16
Variety:	C. P. 44-101	1.41	0.153	1.17
	C. P. 48-103	1.48	0.139	1.19
	C. P. 52-68	1.50	0.154	1.20
	N. Co. 310	1.64	0.182	1.25
Sampling date:	First	1.76	0.174	1.18
	Second	1.40	0.150	1.23
	Third	1.36	0.147	1.19

high number of significant interactions involving time of sampling and other factors in the study appears to be due in part to inconsistent effects of rainfall prior to sampling on leaf-nutrient composition.

It may be noted in Table 5 that rainfall during the three years in the periods one, two, three and four weeks prior to the second sampling was inconsistently associated with leaf nutrient composition. There was some tendency, especially where rainfall differences were relatively large, for rainfall to be positively associated with leaf-N and leaf-K contents and negatively associated with leaf-P content, particularly for the August samplings. Additional work is needed to clarify these relationships.

According to work reported by the authors *(22)*, sugar cane in Louisiana creates a greater stress on available nutrients in early August than in June or September. They reported the rate of uptake of nutrients in early August to be equal to that of June, and considerably greater than that of September. It appears that in early August the supply of available nutrients, especially potassium, drops because the rate of uptake by the crop has been greater than the rate of resupply from unavailable forms. These occurrences suggest that rainfall prior to sampling would have its greatest effect on leaf composition at times of greatest stress on available nutrients. N and K are apparently more responsive to differences in rainfall than P perhaps due in part to their relative ease of mobility and larger quantities needed in the crop.

Correlation values for leaf nutrient contents and yields of sugar cane for the portion of the study in which fertilizer variables were not used were either non-significant or considered not to be of particular importance because these values were so small. It may be noted in Table 14 that correlation values for leaf nutrient contents and yields of sugar cane for the portion of the study which included fertilizer nutrients as variables were significant or highly significant in many cases.

TABLE 4.—Significant F Values from Analysis of Variance of Data Reflecting the Effect of Year, Soil Type, Age of Cane, Variety and Sampling Date on Nutrient Contents of Sugar Cane Leaves

Source of Variation	Degrees of Freedom	F Values N	F Values P	F Values K
Year	2	–	–	–
Soil Type	1	–	–	–
Age	1	8.90*		–
Variety	3	55.81**	105.61**	4.36*
Sampling Date	2	193.53**	62.65**	–
Soil x Date	2	9.19**	11.33**	4.13*
Age x Date	2	–	–	3.35*
Variety x Date	6	4.77**	4.84**	–
Soil x Age x Date	2	–	3.92*	–

*Significant at the 5 per cent level of probability.
**Significant at the 1 per cent level of probability.

TABLE 5.—Effect of Rainfall Prior to Sampling on N, P and K Contents of Sugar Cane Leaves

Location and Soil Type	Year	Sampling Date	Leaf Nutrients N	P	K	Rainfall Prior to Sampling 1 week	2 weeks	3 weeks	4 weeks
Cinclare			%	%	%	Inches	Inches	Inches	Inches
Mhoon sil	1960	June 24	1.77	0.191	1.05	0.18	0.27	1.46	1.46
Mhoon sil	1961	June 15	1.76	0.178	1.10	2.56	2.56	3.06	3.58
Mhoon sil	1962	June 20	1.76	0.180	1.19	0.83	2.16	4.00	4.00
Mhoon sil	1960	Aug. 3	1.38	0.155	1.13	2.14	2.84	5.32	5.43
Mhoon sil	1961	Aug. 3	1.40	0.149	1.48	2.36	2.48	2.78	7.63
Mhoon sil	1962	Aug. 1	1.24	0.160	1.07	0.16	0.21	0.21	0.21
Mhoon sil	1960	Sept. 14	1.34	0.154	1.38	0.18	0.44	3.59	5.82
Mhoon sil	1961	Sept. 20	1.22	0.139	1.14	2.75	8.46	10.17	10.17
Mhoon sil	1962	Sept. 17	1.28	0.137	1.16	0.82	2.29	3.75	4.67
Young's Industries									
Richland sil	1960	June 24	1.67	0.165	1.24	0.00	0.00	0.96	0.96
Richland sil	1961	June 15	1.85	0.156	1.42	0.93	0.93	2.45	5.15
Richland sil	1962	June 20	1.73	0.173	1.10	2.36	3.22	6.34	6.34
Richland sil	1960	Aug. 1	1.53	0.134	1.20	3.07	4.14	7.27	7.86
Richland sil	1961	Aug. 3	1.53	0.148	1.48	0.46	1.83	2.46	4.53
Richland sil	1962	Aug. 1	1.30	0.156	1.06	0.00	0.23	0.69	0.69
Richland sil	1960	Sept. 20	1.52	0.158	1.31	0.00	0.35	0.35	1.45
Richland sil	1961	Sept. 20	1.43	0.144	1.16	2.87	4.98	6.02	13.18
Richland sil	1962	Sept. 17	1.37	0.148	0.98	2.04	2.63	4.02	6.01

The more consistent yield data obtained from the larger-size plots used in the portion of the work which included fertilizer nutrients as variables probably accounts for the better correlation between leaf nutrient contents and yields.

Fertilizer Study

Tables 6 and 7 contain plant nutrient-content and analysis-of-variance data for 1959. The results were analyzed as a complete factorial of three levels of fertilizer N, two levels of fertilizer P_20_5 and two levels of fertilizer K_20 on each soil type at each sampling date. It has been clearly demonstrated *(9, 13)* that a minimum of 40 pounds of N for plant cane and 80 pounds of N for stubble cane may be profitably applied per acre to Louisiana sugar cane annually. In this study, leaf-nutrient data from the check treatment are included for general comparisons. Averages shown immediately below the line for each soil type were calculated without including the check.

The highly significant effect of soil type and sampling date on leaf content of all three nutrients may be noted in Tables 6 and 7. Averages of N content of leaves of cane obtained from the June 10 sampling from each soil type vary from a low of 1.51 per cent N for the Baldwin silty clay loam to a high of 2.25 per cent N for the Jeanerette silt loam. Averages of P content vary from a low of 0.177 per cent for the Baldwin silty clay loam to a high of 0.253 per cent P for the Yahola very fine sandy clay loam. Averages of K content vary from a low of 1.05 per cent K for the Baldwin silty clay loam to a high of 1.70 per cent for the Commerce silt loam.

In Table 3 it may be noted that nutrient contents of N. Co. 310 were higher than those of other varieties. The higher N and P contents of leaves of N. Co. 310 cane grown on the Jeanerette silt loam soil in 1959 and reported in Table 6 are probably due partially to the effect of the variety. The lower K content of cane grown on the Jeanerette silt loam and Baldwin silty clay loam in 1959 can not be explained satisfactorily on the basis of the soil test values shown in Table 1. All examinations of depth of root development of cane grown at the four locations reported in Table 5 revealed a larger volume of roots in the 12-36" depth zone on the Commerce and Yahola soils than was found on the Jeanerette and Baldwin soils, which suggests that periodic subsoiling of Jeanerette and Baldwin soils which have hardpans may be desirable to allow better utilization of soil nutrients and water.

A significant correlation between available K in soils planted to sugar cane in Louisiana during the 10 year period 1954-1963 and yield response to applied fertilizer K has been reported by Ricaud *(29)*. The leaf-K content of cane grown on the four soils reported in Table 6 is better associated with depth of feeding of roots than with top-soil available K, which suggests strongly that depth of feeding of roots should

TABLE 6.—Effect of Fertilizers, Soil Type and Sampling Date on the Nutrient Contents of Sugar Cane Leaves in Four Fertilizer Experiments in 1959

Location, Soil Type and Variety	Rate of N Applied	Leaf N June 10	Leaf N July 21	Leaf N Sept. 10	Leaf N Avg.	Rate of P_2O_5 Applied	Leaf P June 10	Leaf P July 21	Leaf P Sept. 10	Leaf P Avg.	Rate of K_2O Applied	Leaf K June 10	Leaf K July 21	Leaf K Sept. 10	Leaf K Avg.
	Lbs./A.	%	%	%	%	Lbs./A.	%	%	%	%	Lbs./A.	%	%	%	%
Smithfield	check	1.75	1.40	1.32	1.49	check	0.198	0.161	0.145	0.168	check	1.66	1.36	1.22	1.41
Commerce sil	40	1.97	1.54	1.41	1.64	0	0.204	0.172	0.156	0.177	0	1.64	1.34	1.21	1.40
C. P. 36-105	60	1.97	1.53	1.39	1.63	40	0.205	0.175	0.154	0.178	60	1.76	1.42	1.22	1.47
Plant	80	1.98	1.47	1.37	1.61										
Averages of treatments[1]:		1.97	1.51	1.39	1.63		0.205	0.174	0.155	0.178		1.70	1.38	1.22	1.44
Edgefield	check	2.02	1.62	1.25	1.63	check	0.260	0.170	0.142	0.191	check	1.60	1.32	1.21	1.38
Yahola vfsl	40	2.05	1.66	1.30	1.67	0	0.245	0.163	0.140	0.183	0	1.60	1.17	1.16	1.31
C. P. 52-68	60	2.03	1.71	1.34	1.69	40	0.261	0.175	0.141	0.192	60	1.62	1.23	1.18	1.34
Plant	80	2.06	1.73	1.37	1.72										
Averages of treatments[1]:		2.05	1.70	1.34	1.69		0.253	0.169	0.141	0.188		1.61	1.20	1.17	1.33
Alice "B"	check	1.99	1.42	1.19	1.53	check	0.223	0.194	0.188	0.202	check	1.26	1.04	1.31	1.20
Jeanerette sil	40	2.20	1.67	1.40	1.76	0	0.237	0.196	0.189	0.207	0	1.22	1.02	1.27	1.17
N. Co. 310	60	2.28	1.76	1.44	1.83	40	0.263	0.200	0.201	0.221	60	1.44	1.10	1.29	1.28
Plant	80	2.27	1.82	1.47	1.85										
Averages of treatments[1]:		2.25	1.75	1.44	1.81		0.250	0.198	0.195	0.214		1.33	1.06	1.28	1.23
O'Neil	check	1.10	1.10	0.96	1.05	check	0.159	0.141	0.123	0.141	check	1.12	1.20	1.10	1.14
Baldwin sicl	80	1.48	1.25	0.99	1.24	0	0.163	0.145	0.121	0.143	0	1.01	1.09	1.16	1.09
C. P. 44-101	100	1.50	1.25	1.00	1.25	40	0.190	0.151	0.124	0.155	60	1.08	1.12	1.18	1.13
1st stubble	120	1.54	1.31	1.09	1.31										
Averages of treatments[1]:		1.51	1.27	1.02	1.27		0.177	0.148	0.123	0.149		1.05	1.11	1.17	1.11
Averages	check	1.72	1.39	1.18	1.43	check	0.210	0.167	0.150	0.176	check	1.41	1.23	1.21	1.28
of	First rate	1.92	1.53	1.27	1.58	0	0.212	0.169	0.152	0.178	0	1.37	1.15	1.20	1.24
locations	Second rate	1.95	1.56	1.29	1.60	40	0.230	0.175	0.155	0.187	60	1.47	1.22	1.22	1.30
	Third rate	1.96	1.58	1.32	1.62										
Averages of locations and rates[1]:		1.94	1.56	1.29	1.60		0.221	0.172	0.154	0.183		1.42	1.19	1.21	1.27

[1] Averages were calculated without including the check.

be considered when making fertilizer recommendations based on chemical soil test values.

In Table 7 a significant F value is shown for effect of fertilizer N on leaf-N content. This F value shows that there are significant differences among the average N contents of 1.58 per cent N, 1.60 per cent N and 1.62 per cent N for the first, second and third levels of fertilizer N, which are averages of all soil types, fertilizer P_20_5 and K_20 treatments and sampling dates. It may be noted, however, that the greatest differences in leaf-N content are between the check treatment and the first level of fertilizer N used on each soil type. This fact alone illustrates the difficulty associated with the establishment of critical leaf-N values, since almost all Louisiana sugar cane growers apply at least 40 pounds per acre of N to plant cane and 80 pounds per acre of N to stubble cane. It may be further noted that the mean leaf-N contents vary among soil types from a low of 1.27 per cent N to a high of 1.81 per cent N. Based on variety and age differences shown in Table 3, it appears that the portion of this rather wide difference of 0.54 per cent N which may be accounted for by variety and age would be approximately 0.20 per cent. This strongly suggests that a critical value for leaf N would need to be established for each soil type or, perhaps, general soil area if routine leaf analyses are to be used as a basis for recommendations for fertilizer N. The differences noted in rainfall in 1959 at the different locations were not considered to be great enough to influence appreciably the values obtained. Clements (*12*) reports that each locality in the Hawaiian Islands seems to have its own characteristic nitrogen level.

In Table 7 significant F values for the effect of fertilizer N and fertilizer P on leaf P are shown. The significant difference, or increase due to fertilizer P, of averages of leaf-P content, 0.178 per cent P and 0.187 per cent P (Table 6), is small when compared with differences due to soil type. The significance is due to generally consistent differences within soil types and fertilizer treatments on all sampling dates. Due to the wide range of leaf-P values among soil types, however, to establish critical

TABLE 7.—Significant F Values from Analysis of Variance of Data Reflecting the Effect of Fertilizers, Soil Type and Sampling Date on the Nutrient Contents of Sugar Cane Leaves in Four Fertilizer Experiments in 1959

Source of Variation	Degrees of Freedom	F Values		
		N	P	K
N	2	4.15*	4.89*	–
P_2O_5	1	–	32.11**	–
K_2O	1	–	–	35.63**
Soil Type	3	317.55**	289.67**	169.20**
Sampling Date	2	542.66**	173.29**	27.23**

*Significant at the 5 per cent level of probability.
**Significant at the 1 per cent level of probability.

leaf-P values for routine use would require considerable care. The rather large increases due to fertilizer P of leaf-P content of cane grown on the Jeanerette silt loam and Baldwin silty clay loam soils, especially at the first sampling, are associated with relatively low "available" P content of the soils (Table 1) and probably are also due, in part, to restricted depth of root penetration.

Total soil P and available soil P are both usually low (*10, 22*) in Baldwin soils. Response to fertilizer P on Baldwin soils has usually been moderate to high (*10, 22*). A long-term experiment with sugar cane on a Baldwin soil has been initiated to study the effect of lime, rock phosphate and superphosphate, in all possible combinations, on production of sugar cane, when N and K are supplied in sufficient quantities. Since the P content of leaves of cane grown on the Baldwin soil in this study were increased to a relatively strong degree by 40 pounds per acre of fertilizer P_20_5, leaf analysis of cane grown on the new experiment should provide reliable information about the relative effectiveness of the lime, the rock phosphate and the superphosphate, each alone and in all combinations, in providing P for the cane crop.

The highly significant difference, or increase due to fertilizer K, in averages of leaf-K content, 1.24 per cent and 1.30 per cent (Table 6), is small when compared with differences due to soil type. However, the soil type, Jeanerette silt loam, from which some of the highest sugar cane yield responses to fertilizer K in Louisana have been obtained, reveals a greater difference in leaf-blade K than any of the other soil types studied in 1959.

Nutrient contents of cane-leaf samples collected from experiments conducted in 1960 are shown in Table 8. Table 9 contains significant F values obtained from analysis of variance of 1960 data. Three of the four soil types used in the study in 1960 were continuations from work accomplished in 1959 and reported in Table 6. Cane growing on these three soil types in 1960 was stubble cane from the previous crop.

A comparison of nutrient contents from comparable fertilizer treatments on the three soil types studied in 1959 and again in 1960 at the same locations shows that differences were generally greater due to year of sampling than to fertilizer treatment. With the exception of the Baldwin silty clay loam, leaf-N content was generally lower in 1960 than in 1959 even though fertilizer-N treatment on each plot was increased in 1960 by 40 pounds per acre. Except for the September sampling for leaf-K, leaf-P and leaf-K contents for the three soil types were generally lower in 1960 than in 1959. In 1959, rainfall was not a limiting factor for cane growth. However, rainfall in May was so heavy that incomplete cultivation of cane resulted in weed competition for nutrients in the soil. In 1960, cultivation of cane was not a problem, but low rainfall prior to the June and August samplings limited cane growth somewhat.

Frequently yield increases in sugar cane in Louisiana due to fertilizers

TABLE 8.—Effect of Fertilizers, Soil Type and Sampling Date on the Nutrient Contents of Sugar Cane Leaves in Four Fertilizer Experiments in 1960

Location, Soil Type and Variety	Rate of N Applied	Leaf N June 20	Leaf N Aug. 2	Leaf N Sept. 16	Leaf N Avg.	Rate of P_2O_5 Applied	Leaf P June 20	Leaf P Aug. 2	Leaf P Sept. 16	Leaf P Avg.	Rate of K_2O Applied	Leaf K June 20	Leaf K Aug. 2	Leaf K Sept. 16	Leaf K Avg.
	Lbs./A.	%	%	%	%	Lbs./A.	%	%	%	%	Lbs./A.	%	%	%	%
Smithfield	check	1.51	1.30	1.39	1.40	check	0.224	1.163	0.160	0.182	check	1.17	1.04	1.31	1.17
Commerce sil	80	1.78	1.45	1.49	1.57	0	0.195	0.152	0.161	0.169	0	0.94	0.97	1.24	1.05
C. P. 36105	100	1.79	1.43	1.51	1.58	40	0.205	0.154	0.162	0.173	60	1.06	1.02	1.25	1.11
1st stubble	120	1.83	1.46	1.59	1.63										
Average of treatments[1]:		1.80	1.45	1.53	1.59		0.200	0 .153	0.162	0.171		1.00	1.00	1.25	1.08
Little Texas	check	1.58	1.38	1.37	1.44	check	0.198	0.155	0.157	0.170	check	1.08	1.19	1.32	1.23
Mhoon sil	40	1.70	1.43	1.45	1.53	0	0.183	0.154	0.155	0.164	0	1.03	1.14	1.21	1.12
C. P. 52-68	80	1.72	1.44	1.48	1.55	40	0.184	0.153	0.153	0.163	80	1.10	1.18	1.22	1.17
Plant	120	1.74	1.48	1.51	1.58										
Average of treatments[1]:		1.72	1.45	1.45	1.55		0.184	0.154	0.154	0.161		1.07	1.16	1.22	1.15
Alice "B"	check	1.61	1.30	1.24	1.38	check	0.246	0.191	0.173	0.203	check	0.83	0.91	1.20	0.98
Jeanerette sil	80	1.97	1.51	1.51	1.66	0	0.206	0.159	0.183	0.183	0	0.57	0.67	1.13	0.79
N. Co. 310	100	1.96	1.54	1.55	1.68	40	0.230	0.184	0.191	0.202	60	0.92	0.91	1.27	1.03
1st stubble	120	1.93	1.51	1.57	1.67										
Averages of treatments[1]:		1.95	1.52	1.54	1.67		0.218	0.172	0.187	0.193		0.75	0.79	1.20	0.91
O'Neil	check	1.32	1.06	1.00	1.13	check	0.177	0.129	0.126	0.144	check	1.05	1.09	1.21	1.12
Baldwin sicl	80	1.53	1.25	1.10	1.29	0	0.159	0.131	0.132	0.141	0	0.93	1.00	1.25	1.06
C. P. 44-101	100	1.60	1.28	1.22	1.37	40	0.179	0.143	0.144	0.155	60	1.04	1.01	1.28	1.11
2nd stubble	120	1.63	1.29	1.27	1.40										
Average of treatments[1]:		1.59	1.27	1.20	1.35		0.169	0.135	0.138	0.148		0.99	1.01	1.27	1.09
Averages	check	1.51	1.26	1.25	1.34	check	0.211	0.160	0.154	0.175	check	1.03	1.06	1.26	1.12
of	First rate	1.75	1.41	1.39	1.52	0	0.186	0.149	0.158	0.164	0	0.87	0.95	1.21	1.01
locations	Second rate	1.77	1.41	1.44	1.54	40	0.200	0.159	0.163	0.174	60	1.03	1.03	1.26	1.11
	Third rate	1.78	1.44	1.49	1.57										
Averages of locations and rates[1]:		1.77	1.42	1.44	1.54		0.193	0.154	0.161	0.169		0.95	0.99	1.24	1.06

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[1] Averages were calculated without including the check.

is of the order: second stubble > first stubble > plant cane. This may be due partially to a decrease in available soil nutrients, especially potassium, for successive crops. It appears that this factor and rainfall during the period prior to sampling each contributed to some of the differences in leaf-nutrient values obtained on the sites which were sampled in 1959 and again in 1960.

In Table 9 it may be noted that soil type and sampling date in 1960 each influenced leaf contents of all three nutrients to a highly significant degree. Fertilizer N, fertilizer P and fertilizer K resulted in a highly significant increase in average leaf N, average leaf P and average leaf K, respectively. Data in Table 9 also show that fertilizer K and interaction of sampling date and fertilizer P significantly influenced leaf-P content. Interaction of sampling date and fertilizer N had a highly significant effect on leaf-P content. Significant interaction involving sampling date and fertilizer K influenced leaf-K content.

Tables 10 and 11 contain nutrient contents and F values obtained in 1961. Leaf-sheath and internode nutrient contents determined from samples taken from the same plants from which leaf samples were taken have been reported by Londhe *(28)*. From data in Table 10 it may be noted that soil type, sampling date and fertilizer nutrients influenced leaf nutrient contents to varying degrees. The averages of leaf P were not significantly different due to fertilizer P. Fertilizer N had a highly significant influence on leaf K. An examination of the leaf nutrient data used to obtain material reported in Table 10 revealed that an increase in the amount of fertilizer N used normally resulted in a decrease in leaf K.

The data in Tables 10 and 11 show that fertilizer N only up to the 120-pound rate resulted in a significant increase in average leaf N. Londhe *(28)* analyzed samples from the same plants and reported that fertilizer P had no significant influence on leaf-sheath P nor internode P.

TABLE 9.—Significant F Values from Analysis of Variance of Data Reflecting the Effect of Fertilizers, Soil Type and Sampling Date on the Nutrient Contents of Sugar Cane Leaves in Four Fertilizer Experiments in 1960

Source of Variation	Degrees of Freedom	F Values		
		N	P	K
N	2	11.23**	–	–
P_2O_5	1	–	28.24**	–
K_2O	1	–	4.16*	30.17**
Soil type	3	222.17**	109.37**	31.53**
Sampling date	2	437.80**	344.56**	122.52**
N x Sampling date	4	–	5.21**	–
P_2O_5 x Sampling date	2	–	4.52*	–
K_2O x Sampling date	2	–	–	4.53*

*Significant at the 5 per cent level of probability.
**Significant at the 1 per cent level of probability.

TABLE 10.—Effect of Fertilizers, Soil Type and Sampling Date on the Nutrient Contents of Sugar Cane Leaves in Two Fertilizer Experiments in 1961

Location,	Rate of	Leaf N				Rate of	Leaf P				Rate of	Leaf K			
Soil Type and Variety	N Applied	June 9	Aug. 1	Sept. 8	Avg.	P_2O_5 Applied	June 9	Aug. 1	Sept. 8	Avg.	K_2O Applied	June 9	Aug. 1	Sept. 8	Avg.
	Lbs./A.	%	%	%	%	Lbs./A.	%	%	%	%	Lbs./A.	%	%	%	%
Little Texas	check	1.42	1.16	1.26	1.28	check	0.184	0.152	0.148	0.161	check	1.27	1.20	1.32	1.26
Mhoon sil	80	1.71	1.39	1.47	1.52	0	0.193	0.157	0.160	0.170	0	1.02	1.20	1.22	1.15
C. P. 52-58	120	1.77	1.45	1.50	1.57	40	0.197	0.155	0.157	0.170	80	1.36	1.20	1.18	1.25
1st stubble	160	1.76	1.42	1.57	1.58										
Averages of treatments[1]:		1.75	1.42	1.51	1.56		0.195	0.156	0.159	0.170		1.19	1.20	1.20	1.20
Alice "B"	check	1.53	1.39	1.43	1.45	check	0.140	0.160	0.143	0.148	check	0.49	1.09	1.24	0.94
Cypremort sil	80	1.68	1.52	1.47	1.56	0	0.130	0.161	0.135	0.142	0	0.48	1.06	1.08	0.87
C. P. 52-68	120	1.72	1.50	1.48	1.57	40	0.147	0.168	0.141	0.152	80	0.76	1.17	1.19	1.04
1st stubble	160	1.71	1.48	1.49	1.56										
Averages of treatments[1]:		1.70	1.50	1.48	1.56		0.139	0.165	0.138	0.147		0.62	1.12	1.14	0.96
Average	check	1.48	1.28	1.35	1.37	check	0.162	0.156	0.146	0.155	check	0.88	1.15	1.28	1.10
of	First rate	1.70	1.46	1.47	1.54	0	0.162	0.159	0.148	0.156	0	0.75	1.13	1.15	1.01
locations	Second rate	1.75	1.48	1.49	1.57	40	0.172	0.162	0.149	0.161	80	1.06	1.19	1.19	1.15
	Third rate	1.74	1.45	1.53	1.57										
Averages of locations and rates[1]:		1.73	1.46	1.50	1.56		0.167	0.161	0.149	0.159		0.91	1.16	1.17	1.08

[1] Averages were calculated without including the check.

TABLE 11.—Significant F Values from Analysis of Variance of Data Reflecting the Effect of Fertilizers, Soil Type and Sampling Date on the Nutrient Contents of Sugar Cane Leaves in Two Fertilizer Experiments in 1961

Source of Variation	Degrees of Freedom	F Values		
		N	P	K
N	2	6.00*	–	10.97**
P_2O_5	1	–	–	–
K_2O	1	–	–	50.12**
Soil type	1	–	98.83**	157.08**
Sampling date	2	116.00**	3.78*	11.31**

*Significant at the 5 per cent level of probability.
**Significant at the 1 per cent level of probability.

Average leaf K was increased to a highly significant degree as a result of fertilizer K. It was found that the leaf-K value, 1.15 per cent, which is the average value for all treatments receiving 80 pounds of fertilizer K_20, is 14 per cent higher than the leaf-K value, 1.01 per cent, which is the average value for all treatments receiving no fertilizer K_20. The comparable and highly significant value reported by Londhe (*28*) was 18 per cent for increase in leaf-sheath K due to fertilizer K. He reported no significant increase in internode K due to fertilizer K.

The results obtained in 1962 are shown in Tables 12 and 13. In general, the data are similar to results obtained during 1959, 1960 and 1961. It may be noted, however, that fertilizer P had no sinificant influence on average leaf P while fertilizer N resulted in a significant influence on leaf P, and fertilizer K resulted in a significant influence on leaf P. A significant interaction of sampling date and fertilizer K influenced leaf-K content.

Correlations

Table 14 contains correlation coefficients obtained from analysis of relationships between nutrient contents of leaf blades of sugar cane and yields. Nutrient content values from the check, or 0-0-0 treatment, were included in these determinations. It may be noted that there was a high number of significant and highly significant positive relationships between leaf N content and yield. This is attributable to the fact that yield responses to fertilizer N were generally larger and more consistent than yield responses to fertilizer P and fertilizer K. Significant or highly significant correlations between leaf N and yields were obtained in each of the four years for the June sampling.

Based on the data in Table 14, it may be concluded that determination of leaf blade N content as a basis for utilization of fertilizer N on sugar cane in Louisiana offers some promise provided considerable caution is exercised in the interpretation of data. It may be recalled, however, from previous tables that successive levels of fertilizer N above

TABLE 12.—Effect of Fertilizers, Soil Type and Sampling Date on the Nutrient Contents of Sugar Cane Leaves in Three Fertilizer Experiments in 1962

Location,	Rate of	Leaf N				Rate of	Leaf P				Rate of	Leaf K			
Soil Type and Variety	N Applied	June 20	Aug. 1	Sept. 17	Avg.	P_2O_5 Applied	June 20	Aug. 1	Sept. 17	Avg.	K_2O Applied	June 20	Aug. 1	Sept. 17	Avg.
	Lbs./A.	%	%	%	%	Lbs./A.	%	%	%	%	Lbs./A.	%	%	%	%
Alma	check	1.60	1.39	1.06	1.35	check	0.185	0.157	0.104	0.149	check	1.09	1.08	1.04	1.07
Commerce sil	40	1.55	1.39	1.30	1.41	0	0.175	0.156	0.131	0.154	0	1.00	1.10	1.10	1.07
C. P. 52-68	80	1.60	1.40	1.34	1.45	40	0.174	0.152	0.136	0.154	80	1.13	1.13	1.10	1.12
Plant	120	1.63	1.42	1.34	1.46										
Averages of treatments[1]:		1.59	1.40	1.33	1.44		0.175	0.154	0.134	0.154		1.07	1.12	1.10	1.10
Pecan Tree	check	1.34	1.22	1.18	1.25	check	0.199	0.197	0.159	0.185	check	1.43	1.65	1.32	1.47
Sharkey c	40	1.56	1.30	1.16	1.34	0	0.180	0.175	0.145	0.167	0	1.60	1.59	1.34	1.51
C. P. 44-101	80	1.68	1.37	1.21	1.42	40	0.198	0.171	0.139	0.169	80	1.59	1.59	1.32	1.50
Plant	120	1.65	1.35	1.11	1.37										
Averages of treatments[1]:		1.63	1.34	1.16	1.38		0.189	0.173	0.142	0.168		160	1.59	1.33	1.51
Alice "B"	check	1.69	1.29	1.03	1.34	check	0.165	0.174	0.134	0.158	check	0.71	0.80	0.78	0.76
Baldwin sil	40	1.77	1.47	1.08	1.44	0	0.178	0.165	0.125	0.156	0	0.76	0.86	0.65	0.76
N. Co. 310	80	1.80	1.48	1.14	1.47	40	0.192	0.172	0.127	0.164	80	0.95	0.86	0.80	0.87
Plant	120	1.79	1.51	1.16	1.49										
Averages of treatments[1]:		1.79	1.49	1.13	1.47		0.185	0.169	0.126	0.160		0.86	0.86	0.73	0.82
Average	check	1.54	1.30	1.09	1.31	check	0.183	0.176	0.132	0.164	check	1.08	1.18	1.05	1.10
of	First rate	1.63	1.39	1.18	1.40	0	0.178	0.165	0.134	0.159	0	1.12	1.18	1.03	1.11
locations	Second rate	1.69	1.42	1.23	1.45	40	0.188	0.165	0.134	0.162	80	1.22	1.19	1.07	1.16
	Third rate	1.69	1.43	1.20	1.44										
Averages of locations and rates[1]:		1.67	1.41	1.20	1.43		0.183	0.165	0.134	0.161		1.17	1.19	1.05	1.14

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[1] Averages were calculated without including the check.

TABLE 13.—Significant F Values from Analysis of Variance of Data Reflecting the Effect of Fertilizers, Soil Type and Sampling Date on the Nutrient Contents of Sugar Cane Leaves in Three Fertilizer Experiments in 1962

Source of Variation	Degrees of Freedom	F Values		
		N	P	K
N	2	3.79*	3.41*	–
P_2O_5	1	–	–	–
K_2O	1	–	8.62*	21.30**
Soil type	3	13.21**	9.36**	209.14**
Sampling date	2	147.27**	124.25**	22.03**
K_2O x Sampling Date	2	–	–	4.08*

*Significant at the 5 per cent level of probability.
**Significant at the 1 per cent level of probability.

the lowest level used in each experiment did not influence leaf blade N content to the same degree as the initial level. It may also be recalled from previous tables that fertilizer N had a significant influence on leaf P and leaf K contents in several cases. Previous work by the authors (*22*) revealed that P and K contents of sugar cane are generally lowered as fertilizer N is increased. These interactions which influence leaf P and leaf K contents tend to limit the value of routine foliar analysis for leaf P and leaf K as a basis for fertilizer recommendations in Louisiana. In many cases results reported in previous tables have corroborated yield responses previously obtained on similar soil types (*9, 10, 22*). In other cases, a study of leaf P, leaf K, soil P and soil K values and other production factors and their relationships to yield responses has resulted in initiation of special studies which will benefit from foliar analysis as a research tool.

TABLE 14.—Simple Correlation Coefficients between Yields of Sugar Cane and the N, P, K Contents of Sugar Cane Leaves at Each Sampling Date for Each Year of the Study with Fertilizers as Variables.

Year	Sampling Date	r-Value		
		N	P	K
1959	June 10	0.351*	0.096	–0.228
	July 21	0.222	0.466**	–0.337*
	Sept. 10	0.299*	0.599**	0.536**
1960	June 20	0.569**	0.268	0.004
	Aug. 2	0.742**	0.466**	0.174
	Sept. 16	0.714**	0.465**	0.163
1961	June 9	0.742**	0.154	0.252
	Aug. 1	0.351	0.005	0.149
	Sept. 8	0.640**	0.156	–0.091
1962	June 20	0.402**	–0.226	–0.438**
	Aug. 1	0.908**	0.437**	–0.273*
	Sept. 17	–0.347*	–0.736**	–0.301*

*Significant at the 5 per cent level of probability.
**Significnat at the 1 per cent level of probability.

Proposal

Based on results of this study, average standard leaf-nutrient values for sugar cane in Louisiana are proposed for general guidance as shown in Table 15. Values shown are for samples collected when the cane is three months old. Contents of the table should be considered as standard values or corrected for age, variety, soil type or general area and influence of rainfall prior to sampling. Sampling at three months of age or even earlier is necessary if results are to be used during the current year as a basis for fertilization.

TABLE 15.—Standard Leaf-Nutrient Contents[1] for Sugar Cane in Louisiana

Nutritional Status of the Crop	Leaf-Nutrient Content (dry-weight basis)		
	N	P	K
	%	%	%
Very Low	< 1.52	< 0.14	< 1.00
Low	1.25 – 1.50	00.14 – 0.18	1.00 – 1.25
Medium	1.50 – 1.75	0.18 – 0.22	1.25 – 1.75
High	1.75 – 2.00	0.22 – 0.26	1.75 – 2.00
Very High	> 2.00	> 0.26	> 2.00

[1] Standard leaf-nutrient contents should be obtained by applying to analytical data obtained correction factors for age, variety, soil type or general area and rainfall prior to sampling.

Summary and Conclusions

A study has been made of the N, P and K contents of leaf blades of sugar cane and how they are related to year of sampling, soil type, variety, age of cane, time of sampling during the growing season, rainfall prior to sampling, fertilizer treatments and yield. It was found that the average amounts of N, P and K in the leaf blade at three months of age were 1.77 per cent N, 0.188 per cent P and 1.13 per cent K.

For the portion of the study which did not include fertilizer nutrients as variables, leaf nutrient contents revealed no significant differences among years of sampling nor between the soil types or locations due, in part, to a necessary limitation imposed by the method of experimental design and statistical analysis. However, in three of the four years during which studies included fertilizer nutrient variables, differences in leaf nutrient contents were influenced as much, and frequently more, by soil type or location than by fertilizer treatment.

Fertilizer N influenced significant increases in leaf-blade N in most cases. Increases in leaf-blade P and leaf blade K were generally associated positively with fertilizer-P and fertilizer-K treatments, respectively, but the magnitude of the differences was associated with soil test values for "available" P and "available" K, and depth of root development.

Highly significant differences in leaf-blade N, P and K were noted among varieties. The variety N. Co. 310 contained higher amounts of leaf-blade N, P and K than the other varieties, which were all approximately equal in leaf-blade nutrient contents. Previous work has shown that the nutrient requirements of the variety N. Co. 310 for the production of each ton of millable cane are generally higher than other commercial varieties in Louisiana.

Leaf-blade nutrient contents were found to be influenced by significant interactions involving almost all variables studied. These patterns, to some degree unexplainable, together with generally larger differences due to soil type or location than to fertilizer treatment, suggest that routine chemical tests of leaf blades of sugar cane cannot serve alone in Louisiana as a guide in fertilizer applications but may be useful when used in conjunction with results of field trials and chemical soil tests.

It is considered that leaf-blade analysis may be very useful for the research worker as a diagnostic tool when field experiments conducted with fertilizer fail to show results normally obtained or when special treatments not normally used in experiments and about which little information is available are studied for their effect on nutrient composition and yield.

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Factors Influencing Aggregation of Lintonia (Memphis) Richland (Loring) and Olivier Soils in Louisiana

Gaylord L. Hanes
W. H. Willis
Wm. H. Patrick, Jr.

Louisiana State University and
Agricultural and Mechanical College
Agricultural Experiment Station
Doyle Chambers, Director

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Factors Influencing Aggregation Of Lintonia (Memphis), Richland (Loring) And Olivier Soils in Louisiana

GAYLORD L. HANES, W. H. WILLIS AND WM. H. PATRICK, JR.[1]

Introduction

The importance of good soil structure to plant growth and to the ability of the soil to resist the erosive effects of wind and water has long been recognized. The factors that govern the degree and stability of soil structure have been the subject of considerable investigation.

Desirable soil structure results from an orientation of primary soil particles into floccules which become cemented into aggregates possessing varying degrees of stability. The flocculation of these primary particles is essentially a colloidal electrokinetic phenomenon, which is governed by the cations present on the exchange complex and the electrolytes present in the soil solution. Cementation of the floccules has been shown to be effected by organic products of microbiological decomposition, by oxides of iron, silicon, and aluminum, and by clay minerals.

The primary objective of this study was to evaluate the influence of several factors on the aggregation of some silt loam soils of the Pleistocene-Mississippi River terraces in Louisiana.

These soils generally possess a low degree of aggregation and the aggregation present exhibits a poor stability under the impact of raindrops.

The publication of the results of the physical, chemical and X-ray diffraction analyses of the three most important soils of the Mississippi River terraces contributes to the technical data being accumulated and should serve as a basis for better management practices for these soils.

Review of Literature

The literature on the subject of soil aggregation and the factors influencing it is voluminous. No attempt is made here to present a thorough review of the information that has been obtained by numerous investigators. However, some of the more directly related material will be reviewed briefly.

The importance of aggregation on water and air relationships in soil has been studied by Baver (*3*), on susceptability to erosion by Lutz (*13*) and Wilson and Browning (*46*), and on crop yields by Van Bavel and Schaller (*43*), Strickling (*40*) and Page and Willard (*25*).

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[1] Formerly Graduate Assistant, Department of Agronomy, Louisiana State University, later Extension Agronomist, Oklahoma Agricultural Extension Service, Stillwater, Oklahoma, currently Vice President, Best Fertilizers Company, Plainview, Texas; and Professors of Agronomy, Department of Agronomy, Louisiana State University, Baton Rouge, Louisiana, respectively.

The mechanism of flocculation and aggregation and the stability of aggregates have been studied by Baver (*3*), Bradfield (*7*), Sideri (*37*) (*38*), Robinson and Page (*35*) and Wittmuss and Mazurak (*45*).

Among those factors influencing aggregation, organic matter, microorganisms, quantity and kind of clay, free iron oxide, nature of adsorbed cations, cropping systems and seasonal variations have probably received the most attention.

Data obtained by Robinson and Page (*35*) indicated that organic matter associated with the clay fraction and presumably adsorbed on the surfaces of the clay particles was the fraction most effective in aggregate stabilization. The chief cementing agent was the clay with its adsorbed organic matter.

Strickling (*40*) stated that organic matter content was a good indication of soil aggregate stability.

Kroth and Page (*11*) investigated several natural and synthetic cementing substances and concluded that polar substances resulting from decomposition of fresh organic matter were the most effective in aggregating cultivated soils. The more resistant humus, fats, waxes, and resins were also found to be effective.

Reed and Sturgis (*33*) conducted various studies to determine the effects of cropping and flooding on seven soils used for rice production in Louisiana. The effects of repeated cropping and flooding on the physical conditions of Crowley clay loam were measured by aggregate determinations and the rate of water percolation through the soil. Various treatments were initiated in an attempt to improve the physical condition of this soil. The treatment most effective in increasing water percolation and building up structural aggregation was the addition of leguminous organic matter in the form of chopped soybean plants. The addition of 0.8 per cent organic matter to the soil increased the water-stable aggregates from 18 to 30 per cent and increased the average percolation rate, over a 20-month period, from 0.9 to 85.0 c.c. per hour. This was accompanied by a 127.8 per cent increase in the yield of rice.

Alderfer and Merkle (*2*), in measuring structural stability and permeability and the influence of soil treatments on these properties, found that, other things being equal, structural stability was closely correlated with the organic matter content of the soil.

Wilson and Fisher (*47*) studied aggregate increase and stability in two Louisiana soils. They found that increasing the carbon content of Lintonia silt loam increased the percentage of the whole soil in the form of aggregates. Aggregation seemed to approach a maximum at about the 2 per cent carbon level. Olivier silt loam, which was already well aggregated from a previous sod crop, did not respond to additions of organic matter as did the Lintonia soils. Maximum aggregation in the Olivier soil seemed to be reached at about 1.7 to 1.9 per cent carbon.

Bradfield (*7*) emphasized that the best structure was usually found in virgin soils. He agreed with Sideri (*34*) in that interfaces were formed on the surface of the granules. He considered the interfaces to be organic products of the plant roots and microorganisms. Bradfield stated that in undisturbed soil the granules built up a fairly stable interface, and this resulted in what was called water-resistant aggregates.

Browning and Milam (*6*) studied the effect of different types of organic material on soil aggregation and concluded that organic substances which decomposed rapidly increased aggregation within a few days after addition, with maxima being reached in 20 to 30 days, after which they gradually lost their effectiveness. They also found that materials which were slower to decompose required a longer period of time to develop their maximum binding effect, but continued to be effective over a longer period of time.

Patrick, Sturgis and Phillips (*28*), studying the effect of various cropping systems on Richland silt loam soil in Louisiana, obtained significant correlation between per cent soil organic matter and aggregation. Other investigators (*5, 32, 39*) have found that comparatively large differences in organic matter may exist without a proportionate effect on aggregation. Stauffer (*39*), in studying organic carbon and aggregation on the Morrow plots, found that differences of as much as 50 per cent in carbon content existed between some rotations, while differences in aggregation were only slight.

With the aid of an electron microscope, Jackson *et al.* (*10*) were able to show that many soil bacteria had clay particles clustered around them, and some crumbs were simply aggregates of these tiny granules.

During the microbial decomposition of organic residues, soil aggregating substances are produced (*7, 21, 44*). These soil aggregating substances consist of the microbial bodies themselves, decomposition products, and synthesized substances (*15, 16, 18, 19, 22, 34*).

Data presented by Myers and McCalla (*24*) indicated that bacteria were responsible for the aggregation of soil particles only insofar as they were responsible for the accumulation of certain metabolic products that function as cementing materials.

Peele (*29*) found the mucus produced by bacteria to be an effective binding agent in the formation of water-stable soil granules. He obtained mucus produced by various species grown on artificial media and, by incorporating this material into soil, was able to produce water-stable aggregates. This was true whether the soil contained large amounts of clay or consisted entirely of quartz sand.

Martin and Waksman (*17, 18*) found that the extent and duration of the aggregation effect produced by microorganisms and the time required for it to reach a maximum depended upon the nature of the soil, the type of organisms concerned, and the chemical nature of the organic material used, that aggregating effects were greatest in natural soils, and a mixed soil population was most effective in bringing this about.

McCalla (*20*) stated that the increased structure stability resulting from biological activity was temporary, and apparently remained only as long as the stabilizing decomposition products existed. He indicated that quantity of organic residue does not seem as important as quality in producing aggregate stability.

Chesters, Attoe, and Allen (*8*) studied soil aggregation in relation to various soil constituents. In their multiple correlation analysis they found that only a slight relationship existed between organic matter and soil aggregation. The effect of organic matter was conditioned largely by its content of microbial gum. They stated that, in general, microbial gum was the most important single factor in soil aggregation in their investigation.

According to Baver (*3*), the soil colloidal material is responsible for the cementation of primary particles into stable aggregates. He divided the soil colloidal material into at least three distinct groups as far as its cementation effects were concerned. They were clay particles themselves, irreversible or slowly reversible inorganic colloids such as oxides of iron and aluminum, and organic colloids. He pointed out that the cementation effect of clay was more pronounced with the smaller aggregates. As the organic matter content of the soil decreased, clay played a more prominent role, and as the organic matter increased, the effect of clay became insignificant.

Russell (*36*) believed that clay particles aggregate together through the interaction of their exchangeable ions and the charges on their surfaces, with water molecules between the surfaces, and that the binding forces increase as the relative orientations of neighboring clay particles assume certain preferred positions.

Peterson (*30*) attempted to measure the relative capacity of kaolinite and montmorillonite to form water-stable aggregates under the influence of wetting and drying cycles. Kaolinite was found to be very inert as a binding agent, and to have little effect on aggregation. Montmorillonite formed gel-like globules which varied in resistance to dispersion in water according to the conditions of the experiment. The difference in behavoir of the two clays was attributed to the greater surface, hydration, and charge of the montmorillonite in comparison with kaolinite.

According to Baver (*3*), experience in the chemistry of ferric hydroxide has shown that this hydrated colloid becomes almost completely irreversible upon dehydration; this irreversibility of colloidal iron hydroxide is highly important in the production of stable aggregates in many soils, especially the true laterites. Lutz (*12, 14*) studied the physico-chemical properties of iron on laterized soils of North Carolina.

He found that additions of ferric chloride to the soils produced an increase in aeration. In studying the effects of natural free iron oxides on aggregation he concluded that the sesquioxides served a dual purpose. According to Lutz, part of the iron in solution functioned as a flocculating agent, and the other fraction as a cementing agent. In the soils that Lutz studied, iron precipitated as a hydrated gel which, upon dehydration, became a good cementing agent, and the presence of this cementing material on the flocculated clay favored granulation. He concluded that free iron was an important factor influencing the granulation of lateritic and semi-lateritic soils.

Baver *(3)* stated that although it has been generally accepted in the past that the flocculative effect of the calcium ion is the contributing factor for stable granulation, experimental observations indicate that the direct effect of the calcium ion on the aggregation of acid soils is not so important as was originally considered. Baver and Hall *(4)* found a close similarity between the properties of calcium and hydrogen humates. Myers *(23)* reported that hydrogen-humate formed more stable aggregates with clay than did calcium-saturated humus.

Bradfield *(7)* reported on the value and limitations of calcium in soil structure. He concluded that while lime and organic matter may favor the development of good structure in heavy soils, they do not in themselves insure a good granular structure.

When prairie soils are brought under cultivation they maintain good structure for several years, and the structure of cultivated soils can be improved when returned to grass. Russell *(36)* presented evidence which indicated that this factor is associated with the grass roots; also that different species of grasses vary widely in their ability to aggregate the soil.

It seems evident that the effect of tilled crops on soil structure is dependent, to a considerable extent, upon the amount of cultivation that they receive. Woodruff *(48)* studied the effect of various cropping systems on aggregation and concluded that the cropping systems which maintain the organic matter content of the soil will contribute to the maintenance of a higher percentage of water-stable crumbs in the soil. Page *(25)* found soil structure to change rapidly, and that cropping was of prime importance in controlling the type and stability of soil structure. He concluded that a rotation which included a sod-legume mixture was the most effective in improving soil structure.

Patrick, Haddon, and Hendrix *(27)* studied the effect of long-time use of winter cover crops preceding cotton on certain physical properties of Commerce silt loam soil in Louisiana. They found organic matter and total nitrogen content to be highest in hairy vetch plots and lowest in plots which received 40 pounds of nitrogen per acre annually but which did not have a cover crop. The values for aggregation, bulk density, and non-capillary porosity showed that the physical condition of the soil was best in the hairy vetch plots, and poorest in the check plots and the plots receiving 40 pounds of nitrogen per acre.

Materials and Methods

Soils

The soils included in this study were developed from loess or loess-like materials of the late Pleistocene epoch which were deposited by streams, and which now occupy the position of second bottoms or terraces above the present floodplains. The soils are of silt loam texture and include the Linitonia series, classified in the Soil Survey of East Baton Rouge Parish[1] as the Memphis series, which is well drained, the Richland series, now classified as Loring[1], which is moderately well drained, and the Olivier series, somewhat poorly drained. A fourth member of this catena is the poorly drained Calhoun series which was not included in the study.

These soils constitute about 8 per cent of the land area of Louisiana. Approximately 70 per cent of the area occupied by the three soil series studied is in cultivation.

The series descriptions of the Lintonia, Richland and Olivier soils are as follows:

Lintonia.—The surface soil is a brown friable silt loam 10 to 12 inches thick, and moderately acid in reaction. The subsoil is brown silty clay loam 20 to 30 inches thick having a moderate medium subangular blocky structure, and moderately acid in reaction. The underlying substratum ranges from silt loam to fine sandy loam which is moderately acid.

Richland—The surface soil differs from the Lintonia by being slightly darker in color and often contains brown and black concretions. The subsoil is more yellow in color and is mottled. Concretions are also present; a mottled firm and weakly cemented fragipan is present in the lower subsoil.

Olivier—The surface soil is more gray in color than the Richland soils and generally has more brown and black concretions. The subsoil is lighter yellow in color than the Richland series and mottling is more prominent. A predominantly gray fragipan layer is generally present at 14 to 20 inches. The substratum is quite similar to Richland except that the yellow and gray mottling is more highly developed.

Sampling of Profiles

With the exception of four profile samples taken from the Perkins Road Experiment Station Farm in East Baton Rouge Parish, all samples were collected in pairs. The paired samples consisted of those taken from a cultivated site and an adjacent noncultivated site where the soil type and slope were the same. Bulk samples were collected from the A_p horizon or plow-layer of the cultivated soils and the corresponding horizon of the noncultivated sites. The corresponding horizon sampled at noncultivated sites was an A_p horizon in some cases and an A_2 horizon in others. Bulk samples were also taken from the A_3 and B_2 horizons at each site.

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[1] Soil Survey, East Baton Rouge Parish, Louisiana. Scheduled for Publication.

Observations at the time the bulk soil samples were collected revealed that nearly all of the noncultivated areas which were sampled had been in cultivation at some time in the past. It was evident that there was considerable variation in the length of time that these soils had been cultivated and in the length of time that they had been retired from cultivation. Consequently, the noncultivated samples cannot be considered as representing virgin soil conditions. Most of the paired cultivated and noncultivated sample areas were probably cleared and first brought into cultivation at about the same time, and undoubtedly were very similar in chemical and physical properties up to the time that the noncultivated sites were retired from cultivation. Therefore, the chemical and physical differences that were measured in this study have come about, for the most part, due to the influences of continued cultivation on the one hand, and the ameliorative effect of continuous vegetative cover for many years on the other.

Areas Sampled

Forty soil profiles were sampled. Soil samples were collected on an area basis and were assigned the following numerical designations: Area 1, East Feliciana Parish; Area 2, Macon Ridge; Area 3, Opelousas Ridge; and Area 4, East Baton Rouge Parish.

Areas 1 and 4 are Mississippi River terrace soils. However, area 1 has been reworked by a local stream and appears to have been influenced to some extent by Coastal Plain material. The Macon Ridge, designated area 2, is composed of old stream sediments of the Arkansas and Mississippi rivers. The relief of this area is from 15 to 30 feet above the present flood plain of the Mississippi River. The Opelousas Ridge was formed from deltaic deposits of the Red and Mississippi rivers and lies 30 to 50 feet above the adjacent Mississippi River alluvial valley.

The descriptions and locations of the soils studied are shown in Tables 1 and 2.

While the bulk soil samples were still moist they were crushed by hand to pass an 8 mm. sieve, then passed through a sample splitter five times, and placed in one-quart cartons. The cartons of soil were stored in a closet until all samples had reached air dryness. Water-stable aggregate determinations and particle size analyses were then made on these samples.

Samples for pH, cation exchange, and base saturation determinations were prepared by taking a subsample of each air-dry, screened, bulk sample and crushing it to pass an 0.84 mm. sieve (20 mesh).

TABLE 1.—Physical Characteristics of the Soils Studied

Profile	Area	Series	Horizon	Depth	Structure[1]	Consistency	Color[2]	Texture[3]
1-C*	1	Lintonia	A_p	0-6"	Fine granular	Friable	V.dr.gr.br.	si l
			A_3	6-13"	Med. subangular blocky	Friable	Dr.br.	si l
			B_2	18-22"	Str. med. subangular blocky	Friable	Red.br.	si c l
1-NC*	1	Lintonia	A_p	1-6"	Str. fine granular	Friable	Dr.br.	si l
			A_3	10-13"	Str. fine granular and very coarse granular	Friable	Dr.br.	si l
			B_2	18-23"	Str. med. subangular blocky	Friable	Dr.br.	si c l
2-C	1	Olivier	A_p	0-7"	Fine and med. granular	Friable	Dr.gr.br.	si l
			A_3	7-11"	Med. fine subangular blocky	Friable	Dr.br.	si l
			B_2	18-23"	Mod. med. subangular blocky	Friable	Yel.br.(mot. pale br. and gr.br.)	si l
2-NC	1	Olivier	A_p	0-4"	Str. fine granular	Friable	V.dr.gr.	si l
			A_3	4-7"	Mod. med. subangular blocky	Friable	Br.(mot.gr. br. and dr. gr.br.)	si l
			B_2	11-14"	Mod. med. subangular blocky	Friable	Yel.br.	si l
3-C	1	Richland	A_p	0-6"	Med. fine granular	Friable	Dr.br.	si l
			A_3	7-12"	Med. subangular blocky	Friable	Dr.br.	si l
			B_2	18-22"	Str. subangular blocky	Friable	Dr.br.	c l
3-NC	1	Richland	A_p	1-6"	Med. and fine granular	Friable	Dr.gr.br.	si l
			A_3	7-11"	Med. subangular blocky	Friable	Br.	si l
			B_2	18-22"	Str. med. subangular blocky	Friable	Yel.br.	l

[1] Med.-medium; Str.-strong; Mod.-moderate

[2] V.-very; Dr.-dark; Gr.-grayish or gray; Br.-brownish or brown; Red.-reddish or red; Yel.-yellowish; Mot.-mottled

[3] si-silt; l-loam; c-clay

*C-cultivated; NC-noncultivated

TABLE 1.—(Continued)

Profile	Area	Series	Horizon	Depth	Structure	Consistency	Color	Texture
4-C	2	Richland	A_p	0-7”	Mod. med. fine granular	Friable	Dr.br.	si l
			A_3	7-12”	Mod. med. and fine subangular blocky	Friable	Yel.br.	si l
			B_2	18-23”	Mod. med. subangular blocky	Friable	Dr.yel.br.	si l
4-NC	2	Richland	A_p	1-7”	Str. med. fine granular	Friable	Dr.br.	si l
			A_3	7-13”	Mod. med. subangular blocky	Friable	Dr.yel.br.	si l
			B_2	19-24”	Mod. med. subangular blocky	Friable	Dr.yel.br.	si c l
5-C	2	Richland	A_p	0-5”	Mod. med. and fine granular	Friable	Yel.br.	si l
			A_3	5-9”	Mod. med. platy	Friable	Yel.br.	si l
			B_2	13-17”	Str. med. and fine subangular blocky	Friable	Yel.br.	si c l
5-NC	2	Richland	A_p	1-7”	Str. med. fine granular	Friable	Dr.gr.br.	si l
			A_3	7-12”	Mod. fine subangular blocky	Friable	Yel.br.	si l
			B_2	16-211”	Mod. med. and fine subangular blocky	Friable	Yel.br.	si c l
6-C	2	Richland	A_p	0-7”	Str. med. and fine granular	Friable	Br.	si l
			A_3	7-10”	Mod. med. platy	Friable	Dr.yel.br.	si l
			B_2	16-20”	Str. med. and fine subangular blocky	Friable	Dr.yel.br.	si c l
6-NC	2	Richland	A_p	1-5”	Str. med. and fine granular	Friable	Dr.gr.red.br.	si l
			A_3	5-10”	Str. med. and fine subangular blocky	Friable	Dr.br.	si l
			B_2	16-21”	Str. med. and fine subangular blocky	Friable	Yel.br.	si c l

TABLE 1.—(Continued)

Profile	Area	Series	Horizon	Depth	Structure	Consistency	Color	Texture
7-C	2	Richland	A_p	0-5"	Mod. fine granular	Friable	Dr.br.	si l
			A_3	5-10"	Coarse and v. coarse platy	Firm	Br.	si l
			B_2	15-19"	Mod. med. and fine subangular blocky	Friable	Yel.br.	si c l
7-NC	2	Richland	A_p	1-7"	Mod. med. and fine granular	Friable	Yel.br.	si
			A_3	7-15"	Mod. med. platy	Firm	Yel.br.	si l
			B_2	18-22"	Str. med. subangular blocky	Firm	Yel.br.(mot. dr.gr.br. and dr.yel.br.)	si c l
8-C	2	Lintonia	A_p	0-7"	Str. fine granular	Friable	Br.	l
			A_3	7-10"	Mod. med. platy and mod. med. and fine subangular blocky	Firm	Dr.br.	l
			B_2	17-22"	Mod. med. and fine subangular blocky	Friable	Red.br.	c l
8-NC	2	Lintonia	A_p	1-10"	Str. med. fine granular	Friable	V.dr.gr.br.	si l
			A_3	10-15"	Mod. med. coarse subangular blocky	Friable	Br.	si l
			B_2	18-21"	Str. med. coarse subangular blocky	Friable	Br.	c l
9-C	2	Lintonia	A_p	0-5"	Mod. med. and fine granular	Friable	Br.	si l
			A_3	5-11"	Mod. med. and fine subangular blocky	Friable	Br.	si l
			B_2	14-18"	Med. coarse subangular blocky	Friable	Yel.red	c l
9-NC	2	Lintonia	A_p	1-6"	Mod. med. and fine granular	Friable	Br.	si l
			A_3	6-10"	Mod. med. and fine subangular blocky	Friable	Br.	si l
			B_2	17-21"	Mod. med. subangular blocky	Friable	Yel.red	si c l

TABLE 1.—(Continued)

Profile	Area	Series	Horizon	Depth	Structure	Consistency	Color	Texture
10-C	2	Olivier	A_p	0-5"	Mod. fine and med. granular and mod. and coarse platy	sl. firm	Br.	si l
			A_3	5-8"	Mod. med. platy	Firm	Dr.br.	si l
			B_2	16-19"	Mod. med. subangular blocky	Firm	Yel.br. (Mot.pale br. and v. pale br.)	si c l
10-NC	2	Olivier	A_p	1-7"	Mod. med. fine granular	Friable	Br.	si l
			A_3	7-10"	Mod. med. fine granular and mod. med. platy	Friable	Br.	si l
			B_2	20-23"	Mod. med. subangular blocky	Friable	Pale br. (Mot.v.pale br. and yel.br.)	si c l
11-C	2	Richland	A_p	0-5"	Mod. med. and fine granular	Friable	Dr.br.	si l
			A_3	5-8"	Mod. med. platy (horizontal lens of brown silt)	Firm	Dr.br.	si l
			B_2	17-23"	Mod. med. subangular blocky	Friable	Dr.br.	si c l
11-NC	2	Richland	A_p	1-4"	Mod. med. and fine granular	Friable	Br.	si l
			A_3	4-6"	Mod. med. and fine granular	Friable	Br.	si l
			B_2	17-20"	Str. med. subangular blocky	Friable	Dr.br.	si c l
12-C	2	Richland	A_p	0-5"	Mod. med. and fine granular	Friable	Dr.br.	si l
			A_3	5-8"	Weak med. platy and mod. med. subangular blocky	Firm	Dr.br.	si l
			B_2	16-20"	Str. med. subangular blocky	Mod. friable	Dr.yel.br.	si c l
12-NC	2	Richland	A_p	1-5"	Mod. med. and coarse granular	Friable	Dr.br.	si l
			A_3	5-8"	Weak med. platy and mod. med. subangular blocky	Sl. firm	Dr.br.	si l
			B_2	16-20"	Mod. med. subangular blocky	Friable	Yel.br.	Si c l
13-C	2	Richland	A_p	0-5"	Mod. coarse granular and med. coarse subangular blocky	Firm	Dr.br.	si l
			A_3	5-8"	Weak med. platy and mod. med. subangular blocky	Firm	Dr.br.	si l
			B_2	16-20"	Mod. med. subangular blocky	Friable	Dr.br.	si c l

TABLE 1.–(Continued)

Profile	Area	Series	Horizon	Depth	Structure	Consistency	Color	Texture
13-NC	2	Richland	A_p	0-5"	Mod. fine and med. granular	Friable	Dr.yel.br.	si l
			A_3	5-8"	Mod. med. platy and med. subangular blocky	Firm	Dr.yel.br.	si l
			B_2	19-22"	Mod. med. subangular blocky	Friable	Yel.br.	si c l
14-C	2	Richland	A_p	0-6"	Mod. med. and fine granular	Friable	Br.	si l
			A_3	6-10"	Mod. med. platy and mod. med. subangular blocky	Friable	Br.	si c l
			B_2	19-22"	Str. med. fine subangular blocky	Friable	Br.	si c l
14-NC	2	Richland	A_p	1-7"	Mod. med. and coarse granular	Friable	Br.	si l
			A_3	7-10"	Mod. med. and fine granular	Firm	Br.	si l
			B_2	19-22"	Mod. med. subangular blocky	Friable	Br.	si c l
15-C	3	Richland	A_p	0-6"	Str. fine granular	Friable	Dr.br.	si l
			A_3	6-9"	Mod. med. and fine granular	Friable	Dr.br.	si l
			B_2	17-21"	Mod. med. and fine subangular blocky	Friable	Dr.br.	si c l
15-NC	3	Richland	A_p	1-6"	Mod. med. platy and mod. fine granular	Firm	Dr.gr.br.	si l
			A_3	6-10"	Str. fine granular and mod. med. platy	Firm	Dr.gr.br.	si l
			B_2	16-20"	Str. med. subangular blocky	Firm	Dr.yel.br.	si c l
16-C	3	Olivier	A_p	0-6"	Str. fine granular	Friable	Dr.gr.br.	si l
			A_3	6-10"	Mod. med. platy	Firm	Dr.yel.br.	si l
			B_2	15-19"	Mod. med. and fine subangular blocky	Firm	Yel.br.(mot. light yel.br.)	si c l
16-NC	3	Olivier	A_p	10-14"	Mod. med. granular	Friable	Dr.gr.br.	si l
			A_3	14-18"	Mod. med. granular and mod. fine subangular blocky	Firm	Dr.br.	si l
			B_2	20-24"	Mod. med. and coarse subangular blocky	Firm	Yel.br.(mot. br.gr.)	si c l

TABLE 1.—(Continued)

Profile	Area	Series	Horizon	Depth	Structure	Consistency	Color	Texture
17-C	3	Richland	A_p	0-6"	Str. fine granular	Friable	Br.	si l
			A_3	6-10"	Str. med. platy	Firm	Br.	si l
			B_2	14-18"	Med. subangular blocky	Firm	Dr.br.	si c l
17-NC	3	Richland	A_p	1-6"	Str. fine granular	Friable	Br.	si l
			A_3	6-9"	Str. med. platy	Firm	Dr.br.	si l
			B_2	17-21"	Mod. med. subangular blocky	Firm	Dr.br.	si l
18-C	4	Olivier	A_p	0-5"	Med. fine granular	Friable	Br.	si l
NP*			A_3	5-8"	Med. platy	Sl. firm	Br.	si l
			B_2	8-16"	Mod. med. subangular blocky	Friable	Yel.br.(mot. light br.gr.)	si c l
19-C	4	Olivier	A_p	0-5"	Mod. med. granular	Friable	Br.	si l
NP*			A_3	5-7"	Mod. med. platy	Firm	Gr.br.	si l
			B_2	7-14"	Mod. med. subangular blocky	Friable	Br.(mot.yel. br. and br.gr.)	si c l
20-C	4	Olivier	A_p	0-5"	Mod. med. granular	Friable	Gr.br.	si l
NP*			A_3	5-8"	Mod. med. platy	Firm	Gr.br.	si l
			B_2	8-16"	Mod. med. and coarse subangular blocky	Friable	Yel.br.(mot. br. and br.gr.)	si c l
21-C	4	Olivier	A_p	0-4"	Mod. med. granular	Friable	Br.	si l
NP*			A_3	4-7"	Mod. med. platy	Firm	Gr.br.	si l
			B_2	7-16"	Mod. coarse subangular blocky	Friable	Yel.br.(mot. br. and br.gr.)	si l
22-C	4	Olivier	A_p	0-4"	Mod. med granular	Friable	Gr.br.	si l
			A_3	4-8"	Str. thin and med. platy	Firm	Gr.br.	si l
			B_2	8-16"	Mod. med. subangular blocky	Friable	Yel.br.(mot.br.gr.)	si l
22-NC	4	Olivier	A_p	0-3"	Mod. med. granular	Friable	Gr.br.	si l
			A_3	3-8"	Weak med. subangular blocky	Friable	Gr.br	si l
			B_2	8-12"	Mod. med. subangular blocky	Friable	Yel.br.(mot.br.gr.)	si c l

*NP—Nonpaired sample, no corresponding noncultivated sample.

TABLE 2.—Location of Soil Sample Sites

Profile	Area	Series	Location
1-C*	1	Lintonia	Idlewild Plantation, S. E. of Clinton (cultivated)
1-NC*	1	Lintonia	20 yards from 1-C (noncultivated, woods)
2-C	1	Olivier	Idlewild Plantation, S. E. of Clinton (cultivated)
2-NC	1	Olivier	Idlewild Plantation (noncultivated, woods)
3-C	1	Richland	Idlewild Plantation (cultivated)
3-NC	1	Richland	Idlewild Plantation (noncultivated, woods)
4-C	2	Richland	20 yards south of 4-NC (cultivated)
4-NC	2	Richland	Macon Ridge Experiment Station, 50 yards west of gate (old fence row)
5-C	2	Richland	30 yards from 5-NC (cultivated)
5-NC	2	Richland	2N-½W of Crowville (noncultivated, fence row)
6-C	2	Richland	5 ¾ mi. south of Epps (cultivated)
6-NC	2	Richland	20 yards north of 6-C (noncultivated, fence row)
7-C	2	Richland	5 mi. S. E. of Oak Grove (cultivated)
7-NC	2	Richland	100 yards from 7-C (noncultivated)
8-C	2	Lintonia	9 mi. south of Rayville (cultivated)
8-NC	2	Lintonia	50 yards from 8-C (noncultivated, fence row)
9-C	2	Lintonia	2 ¾ mi. N. W. of Rayville (cultivated)
9-NC	2	Lintonia	20 yards from 9-C (noncultivated, fence row)
10-C	2	Olivier	1 mi. west of Oak Grove (cultivated)
10-NC	2	Olivier	20 yards from 10-C (noncultivated, fence row)
11-C	2	Richland	6 mi. N. E. of Oak Grove (cultivated)
11-NC	2	Richland	20 yards from 11-C (in grass a few years)
12-C	2	Richland	Macon Ridge Experiment Station (cotton following vetch)
12-NC	2	Richland	Macon Ridge Experiment Station (Bermudagrass-clover sod)
13-C	2	Richland	Macon Ridge Experiment Station (continuous cotton, no nitrogen)
13-NC	2	Richland	Macon Ridge Experiment Station (first year cotton following bermudagrass-clover sod)
14-C	2	Richland	2 mi. N. W. of Wisner (cultivated)
14-NC	2	Richland	20 yards from 14-C (noncultivated, fence row)
15-C	3	Richland	2 mi. north of Youngsville (cultivated)
15-NC	3	Richland	10 yards from 15-C (noncultivated, turn row)
16-C	3	Olivier	2 mi. N. W. of Youngsville (cultivated)
16-NC	3	Olivier	15 yards from 16-C (buried by recent roadbed construction with more top soil) (noncultivated)
17-C	3	Richland	Billeaud Plantation, south of Youngsville (cultivated)
17-NC	3	Richland	30 yards from 17-C (in Bermudagrass pasture a few years)
18-C NP**	4	Olivier	Perkins Road Agronomy Farm, cotton-corn vetch rotation, N. W. replication, 20 ft. from south end of plot (corn, 8-8-8 fertilizer)
19-C NP**	4	Olivier	Perkins Road Agronomy Farm, cotton-corn-vetch rotation, N. W. replication, 20 ft. from south end of plot (corn, 8-0-8 fertilizer)
20-C NP**	4	Olivier	Perkins Road Agronomy Farm, cotton-corn-vetch rotation, N. W. replication, 20 ft. from south end of plot (corn, no fertilizer)
21-C NP**	4	Olivier	Perkins Road Agronomy Farm, cotton-corn-vetch rotation, N. W. replication, 20 ft. from south end of plot (corn, 0-8-8 fertilizer)
22-C	4	Olivier	Perkins Road Agronomy Farm, 15 yards west of 22-NC (inbred corn plots)
22-NC	4	Olivier	Perkins Road Agronomy Farm, Dallisgrass seed increase block

*C-cultivated, NC-noncultivated.

**NP—Nonpaired sample, no corresponding noncultivated sample.

Additional subsamples were taken from the processed bulk samples. These subsamples were prepared by washing the soil with water through a 0.42 mm. (35-mesh) sieve for the purpose of removing larger concretions. The wet soil samples were then placed in a forced-draft oven at 65° C. for drying. After the samples were dried, they were crushed in a mortar to pass a 0.25 mm. (60-mesh) sieve and the moisture content was allowed to come to equilibrium with the atmosphere. The samples were then stored in screw-cap glass jars until used for free iron oxide, organic carbon, and total nitrogen determinations.

Analyses

Aggregate Determinations—Water-stable aggregates greater than 4.76, 2.0, 1.0, and 0.21 mm. were determined on duplicate samples by wet sieving for 10 minutes, using the procedure outlined by van Bavel (*42*). Per cent water-stable aggregates greater than 1.00 mm., and greater than 0.21 mm. were calculated for each sample. The maximum allowable variation between duplicate samples was 5 per cent of the sample weight. Aggregation, as reported in this study, is the percentage of primary soil particles bound together into secondary units or aggregates of a certain size (0.21 mm. or 1.00 mm.) and stable enough to resist the slaking effect of water for 10 minutes.

Particle Size Analysis—Per cent sand, silt, and clay were determined on duplicate 40-g. air-dry samples of the processed bulk samples with an A.S.T.M. hydrometer, 152H, by the method outlined by Day (*9*) and modified by Patrick (*26*).

Cation Exchange Complex Determinations—Duplicate 25-gram samples of 20-mesh soil material were used to determine total cation exchange capacity, calcium, magnesium, potassium, and sodium saturation. Results of these determinations are reported in m.e. per 100 grams of dry soil. Maximum error in cation exchange capacity determinations between duplicate samples was 0.1 m.e. per 100 grams of soil. The procedure consisted of shaking 25 grams of 20-mesh soil in 100 ml. of 1N ammonium acetate adjusted to pH 7.0 and allowing the suspension to stand overnight. A Buchner funnel was fitted with a moist No. 42 Whatman filter paper and a low suction applied. The sample was stirred, poured into the funnel and washed with an additional 150 ml. of the 1N ammonium acetate. This 10 to 1 leachate extraction was adjusted to volume and saved for base determinations. Without being allowed to dry the soil was then washed with 250 ml. of ethyl alcohol to remove excess ammonia and then placed in a 500 ml. Kjeldahl flask for ammonia distillation. Two hundred fifty ml. of distilled water, 5 grams of sodium chloride, 12 ml. of 1N sodium hydroxide, and 5 drops of 2-octanol as an antifoam agent, were added to the sample for distillation. The ammonia was trapped in 0.1N sulfuric acid and back-titrated to pH 6.5 with 0.1N sodium hydroxide.

Calcium, magnesium, potassium, and sodium determinations were made on a Beckman DU spectrophotometer. Standards of these bases were also prepared in 1N ammonium acetate.

pH—Triplicate samples of 20-mesh soil were prepared in a 1:1 soil-water suspension and allowed to stand overnight. The pH of the soil samples was determined with a Beckman Zeromatic pH meter which was standardized at pH 7.0 and 5.0.

Organic Matter—Organic carbon was determined on duplicate soil samples in a dry combustion apparatus by the method described by Piper (*31*). Carbon was converted to organic matter by the factor 1.724. The combustion tube was heated to 950° C. Oxygen was passed through the system to convert the carbon to CO_2. The liberated CO_2 was trapped in absorption bulbs containing ascarite and was weighed.

Nitrogen—Total nitrogen was determined by the Kjeldahl method. Samples of approximately 10 grams of soil were accurately weighed and digested in sulfuric acid with Kel-pack as a source of salt. The ammonia was distilled into 2 per cent boric acid and titrated to pH 5.5 with 0.1N H_2SO_4 on a Beckman automatic titrator.

Free Iron Oxides—This determination was made by use of a slight modification of the procedure outlined by Aguilera and Jackson (*1*). Two grams of soil was placed in a 60 ml. centrifuge tube, and 20 ml. of 0.3M sodium citrate, pH 7.3 and containing 60 ml. of 1M $NaHCO_3$, was added as a buffer. The temperature was brought to 80° C. in a water bath, 0.5 g. of $Na_2S_2O_4$ was added as a reducing agent and the sample was stirred frequently for 15 minutes. After 15 minutes, 5 ml. of saturated NaCl as a flocculating agent was added by hypodermic syringe. The sample remained one minute longer in the water bath and was then immediately centrifuged for five minutes at 2200 rpm; the supernatant liquid was poured off into a 500 ml. Erlenmeyer flask for iron determination. The procedure was then repeated on the same soil sample. Investigation showed that on the soils used in this study the first extraction removed 65 to 85 per cent of the removable free iron oxide. The second extraction removed 15 to 35 per cent. A third extraction removed about one per cent or only a trace. Therefore, it was concluded that two extractions were sufficient for reliable free iron oxide determinations on these soils.

The supernatant liquid containing the removed iron was then heated over a steam bath at 90° C. for one hour, then 30 per cent H_2O_2 was added dropwise until a full yellow color developed. The solution was allowed to cool. A few drops of 6N HCl were added to test for turbidity. If turbidity developed, due to presence of elemental sulfur, the heating was continued another 30 minutes. If no turbidity developed, the remainder of 5 ml. of 6N HCl and 1 ml. of H_2O_2 were added. The sample was made up to volume in a 250 ml. volumetric flask, and in two steps was diluted to 2,500 to 1 on the basis of soil weight. The iron determination was made by placing 25 ml. of the diluted extract in a 50 ml. volumetric flask, adding by hypodermic syringes 1 ml. of 30 per cent H_20_2, followed by 5 ml. of 6N HC1, 5 ml. of 20 per cent KSCN, and then making the solution up to volume for a 5,000 to 1 dilution. Ten minutes after the KSCN was injected, the per cent transmission of the Fe $(SCN)_3$ colored solution was determined on a Bausch and Lomb "Spectronic 20" spectrophotometer at a maximum light transmission of 500 millimicrons. A standard curve was established using pure iron wire. The spectrophotometer was adjusted at 100 per cent transmission on a water blank. The 5,000 to 1 dilution was selected so as to have a final iron concentration of 0.5 to 3.0 ppm. This concentration allowed transmission readings to be made in the most accurate range of the curve, which was between 20 and 80 per cent transmission.

Samples of the A_p and B_2 horizons of six of the soil profiles studied were subected to X-ray diffraction analyses to determine the kind and distribution of mineral colloids present. The analyses and interpretations were made on a contract basis at Texas A. and M. College by Dr. G. W. Kunze.

Results and Discussion

Results of the physical and chemical analyses on the three soils are presented in Tables 3, 4, and 5. The means for the results on each horizon on cultivated and noncultivated sites for all the soils are reported in Table 6. Means for analytical results on all A_p horizons sampled are presented for cultivated and noncultivated soils in Table 7. Means for analytical results on A_p horizons for each of the four sampled soil areas are shown in Tables 8 and 9. In Table 10, the means of the results obtained on samples of cultivated soils in all areas are presented by horizons for each of the three soil series. Physical and chemical characteristics of the horizons of cultivated and noncultivated Richland soils on the Macon Ridge are shown in Table 11. The results of x-ray diffraction analyses of samples of A_p and B_2 horizons of six of the soil profiles studied are shown in Table 12.

The data presented in Table 3 show that the sand content of the soils in East Feliciana Parish and the four Lintonia profiles from the Macon Ridge was considerably higher than that of any of the other soils studied. Much of the sand in the soils of East Feliciana was probably of Coastal Plain origin. The Lintonia profiles with high sand contents on the Macon Ridge were sampled near the Boeuf River.

As is shown in Table 6, the average content of water-stable aggregates greater than 0.21 mm. in the A_p horizon of the cultivated soils was 29.1 per cent, compared with 58.3 per cent in the noncultivated soils. An even greater relative difference existed between the two groups of soils in the content of aggregates greater than 1 mm. In this case the averages were 14.5 and 37.3 per cent for the cultivated and noncultivated soils, respectively. This represents decreases, due to cultivation, of 61 per

TABLE 3.—Analytical Data on Physical and Chemical Properties of Pleistocene Terrace Soils

Profile	Area	Horizon	Texture	Sand %	Silt %	Clay %	Free Fe_2O_3 %	Primary Particles >0.21 mm %	pH
Lintonia									
1-C	1	A_p	Si l	32.9	54.5	12.6	2.53	23.0	5.1
		A_3	Si l	20.3	61.0	18.7	2.79	13.2	5.2
		B_2	Si c l	17.6	48.6	33.8	5.22	9.8	5.0
1-NC	1	A_p	Si l	8.5	68.4	23.1	3.25	6.0	4.8
		A_3	Si l	21.7	63.2	15.1	2.35	11.8	4.8
		B_2	Si c l	16.7	54.1	29.2	4.13	7.6	4.5
Olivier									
2-C	1	A_p	Si l	21.9	50.9	27.2	2.03	11.6	6.2
		A_3	Si l	20.8	61.4	17.8	2.44	12.2	4.9
		B_2	Si l	21.0	53.8	25.2	4.25	11.2	4.7
2-NC	1	A_p	Si l	19.3	68.0	12.7	1.92	6.0	5.1
		A_3	Si l	11.7	72.8	15.5	2.39	9.8	5.0
		B_2	Si l	12.9	69.0	18.1	2.84	4.6	4.8
Richland									
3-C	1	A_p	Si l	31.3	51.8	16.9	1.91	13.8	6.3
		A_3	Si l	28.4	54.6	17.0	2.97	12.6	5.0
		B_2	C l	20.5	50.5	29.0	5.74	6.0	4.6
3-NC	1	A_p	Si l	28.0	56.4	15.6	2.46	19.2	5.2
		A_3	Si l	29.6	54.6	15.8	2.61	0.5	4.8
		B_2	L	31.5	45.4	23.1	4.64	1.0	4.8
4-C	2	A_p	Si l	7.0	80.0	13.0	2.06	0.6	5.7
		A_3	Si l	4.1	80.6	15.3	2.39	3.0	5.6
		B_2	Si c l	1.2	61.4	37.4	5.63	0.6	4.7
4-NC	2	A_p	Si l	7.9	77.9	14.2	2.28	1.0	6.2
		A_3	Si l	1.0	78.0	21.0	2.99	0.8	6.2
		B_2	Si c l	0.6	66.8	32.6	5.15	0.2	5.6
5-C	2	A_p	Si l	10.0	79.6	10.4	1.37	2.0	6.4
		A_3	Si l	3.2	76.4	20.4	2.06	1.4	5.4
		B_2	Si c l	0.0	67.2	32.8	3.81	0.8	5.0
5-NC	2	A_p	Si l	3.9	82.3	13.8	2.05	0.2	6.5
		A_3	Si l	4.8	73.6	21.6	2.86	0.4	6.4
		B_2	Si c l	2.8	62.6	34.6	5.53	0.2	5.1
6-C	2	A_p	Si l	5.5	77.1	17.4	2.24	1.0	4.9
		A_3	Si l	3.6	73.1	23.3	2.94	0.8	4.8
		B_2	Si c l	4.3	58.5	37.2	5.70	0.0	4.8
6-NC	2	A_p	Si l	9.6	73.8	16.6	2.15	1.8	5.6
		A_3	Si l	8.3	73.1	18.6	2.61	1.2	5.5
		B_2	Si c l	3.6	59.7	36.7	5.40	0.2	4.8
7-C	2	A_p	Si l	9.1	78.3	12.6	1.76	1.0	4.9
		A_3	Si l	5.8	71.0	23.2	2.97	0.0	4.8
		B_2	Si c l	3.0	60.3	36.7	5.41	1.6	4.6
7-NC	2	A_p	Si	5.6	85.7	8.7	1.62	1.0	6.7
		A_3	Si l	16.0	68.7	15.3	2.45	0.0	6.4
		B_2	Si c l	9.9	57.4	32.6	4.79	1.6	5.0

TABLE 3.–(Continued)

Profile	Area	Horizon	Texture	Sand %	Silt %	Clay %	Free Fe_2O_3 %	Primary Particles >0.21 mm %	pH
Lintonia									
8-C	2	A_p	L	47.3	42.7	10.3	1.68	9.6	6.5
		A_3	L	35.3	46.9	17.8	2.61	6.4	6.4
		B_2	C l	27.1	38.8	34.1	5.31	6.0	4.8
8-NC	2	A_p	Si l	35.8	54.1	10.1	1.68	5.0	5.8
		A_3	Si l	29.4	56.2	14.4	1.91	6.0	6.5
		B_2	C l	20.5	51.3	28.2	4.13	3.4	6.1
9-C	2	A_p	Si l	32.0	58.4	9.6	0.70	0.6	5.3
		A_3	Si l	25.0	62.3	12.7	1.20	0.2	4.9
		B_2	C l	27.3	44.7	28.0	2.27	0.2	4.8
9-NC	2	A_p	Si l	33.3	58.4	8.3	0.83	0.8	5.4
		A_3	Si l	23.3	63.9	12.8	1.07	0.2	5.4
		B_2	Si c l	17.3	53.8	28.9	2.43	0.2	5.0
Olivier									
10-C	2	A_p	Si l	6.0	77.0	17.0	2.47	3.6	5.8
		A_3	Si l	5.4	70.8	23.8	3.36	3.2	5.5
		B_2	Si c l	6.5	64.9	28.6	4.06	10.0	5.1
10-NC	2	A_p	Si l	8.0	79.0	13.0	2.21	6.8	5.8
		A_3	Si l	6.3	73.2	20.5	2.52	5.0	5.7
		B_2	Si c l	6.1	65.6	28.3	4.12	4.6	4.7
Richland									
11-C	2	A_p	Si l	7.4	74.0	18.6	2.43	2.0	6.8
		A_3	Si l	7.5	73.1	19.4	2.50	1.2	6.8
		B_2	Si c l	2.3	60.2	36.5	5.57	0.4	6.5
11-NC	2	A_p	Si l	8.8	76.4	14.8	1.81	2.2	6.0
		A_3	Si l	7.8	76.2	16.0	2.72	1.6	5.9
		B_2	Si c l	3.7	59.4	36.9	5.49	0.4	4.8
12-C	2	A_p	Si l	8.6	76.6	14.8	2.36	6.2	6.8
		A_3	Si l	7.6	77.4	15.0	2.35	2.8	6.7
		B_2	Si c l	4.0	60.3	35.7	5.51	1.4	4.8
12-NC	2	A_p	Si l	8.6	76.1	15.3	2.20	2.2	6.5
		A_3	Si l	4.6	70.3	25.1	3.22	1.6	5.6
		B_2	Si c l	3.0	62.0	35.0	4.73	2.8	4.9
13-C	2	A_p	Si l	7.8	77.5	14.7	2.19	3.0	6.7
		A_3	Si l	7.3	73.3	19.4	2.42	2.2	6.6
		B_2	Si c l	3.1	62.1	34.8	5.97	3.6	4.8
13-NC	2	A_p	Si l	7.6	75.1	17.3	2.35	2.8	5.6
		A_3	Si l	4.2	75.2	20.6	2.54	3.0	5.7
		B_2	Si c l	2.0	62.8	35.2	6.10	7.4	4.8
14-C	2	A_p	Si l	6.9	83.5	9.6	1.52	2.0	6.6
		A_3	Si l	8.0	82.4	9.6	1.74	4.4	6.3
		B_2	Si l	6.8	67.7	25.5	2.82	5.8	4.7
14-NC	2	A_p	Si l	12.6	77.7	9.7	1.37	6.4	6.1
		A_3	Si l	8.6	79.1	12.3	1.48	5.0	5.6
		B_2	Si c l	8.0	63.9	28.1	2.85	6.2	4.9

TABLE 3.—(Continued)

Profile	Area	Horizon	Texture	Sand %	Silt %	Clay %	Free Fe_2O_3 %	Primary Particles >0.21 mm %	pH
Richland (continued)									
15-C	3	A_p	Si l	8.5	73.9	17.6	2.09	1.0	5.1
		A_3	Si l	7.0	76.9	16.1	2.08	1.0	4.6
		B_2	Si c l	3.9	63.9	32.3	4.14	0.0	5.0
15-NC	3	A_p	Si l	9.6	73.0	17.4	2.05	1.0	5.2
		A_3	Si l	6.8	73.2	20.0	2.33	0.4	5.0
		B_2	Si c l	3.5	62.5	34.0	4.06	0.2	5.0
Olivier									
16-C	3	A_p	Si l	8.4	73.6	18.2	2.08	0.8	4.9
		A_3	Si l	6.2	70.9	22.7	2.32	1.6	4.7
		B_2	Si c l	5.5	66.4	28.1	2.77	0.4	4.9
16-NC	3	A_p	Si l	8.2	73.6	18.2	2.09	0.6	4.9
		A_3	Si l	7.6	69.7	22.7	2.32	1.4	4.8
		B_2	Si c l	5.3	65.2	29.5	3.05	0.2	4.7
Richland									
17-C	3	A_p	Si l	9.7	72.9	17.4	2.70	1.0	5.0
		A_3	Si l	8.5	70.0	21.5	2.92	0.8	5.0
		B_2	Si c l	4.4	69.0	26.6	3.95	0.0	5.2
17-NC	3	A_p	Si l	9.7	74.4	15.9	2.22	1.2	6.1
		A_3	Si l	6.4	70.0	23.6	3.33	0.2	4.9
		B_2	Si l	5.8	80.1	14.1	4.07	0.0	5.0
Olivier									
18-C (non-paired)	4	A_p	Si l	11.4	79.8	8.8	1.56	2.6	6.1
		A_3	Si l	12.6	76.3	11.1	1.68	1.8	6.2
		B_2	Si c l	4.9	63.5	31.6	4.56	0.4	4.7
19-C (non-paired)	4	A_p	Si l	10.8	77.3	11.9	2.01	1.2	5.4
		A_3	Si l	7.2	73.5	19.3	2.72	1.6	5.3
		B_2	Si c l	5.0	62.9	32.1	4.82	1.6	4.7
20-C (non-paired	4	A_p	Si l	8.2	82.2	9.6	1.88	2.0	5.9
		A_3	Si l	11.4	79.0	9.6	1.64	2.0	6.0
		B_2	Si c l	9.0	63.4	27.6	4.94	1.0	4.9
21-C (non-paired)	4	A_p	Si l	10.8	74.5	14.7	2.49	2.0	5.7
		A_3	Si l	7.6	68.3	24.1	3.80	0.6	4.9
		B_2	Si l	7.6	68.3	24.1	3.80	0.6	4.9
22-C	4	A_p	Si l	16.2	77.2	6.6	1.40	8.2	6.7
		A_3	Si l	17.2	78.0	6.8	1.33	7.6	6.6
		B_2	Si l	11.3	68.7	20.0	2.42	3.6	4.9
22-NC	4	A_p	Si l	14.2	74.3	11.5	2.08	6.6	5.9
		A_3	Si l	14.3	76.0	9.7	1.77	5.8	6.0
		B_2	Si c l	8.4	64.2	27.4	4.00	2.2	4.8

cent in aggregates greater than 1 mm., and 50 per cent in aggregates greater than 0.21 mm. The influence of cultivation was also reflected in the state of aggregation of the A_3 horizons. In this case the content of aggregates greater than 1 mm. decreased from 17.8 per cent in the

TABLE 4.—Analytical Data on Physical and Chemical Properties of Pleistocene Terrace Soils

Profile	Area	Horizon	Organic Matter %	Carbon %	Nitrogen %	C:N Ratio	Aggregates >1.00 mm %	Aggregates >0.21 mm %
Lintonia								
1-C	1	A_p	1.412	0.819	0.089	9.2	26	46
		A_3	0.685	0.397	0.055	7.2	31	49
		B_2	0.459	0.266	0.057	4.7	5	52
1-NC	1	A_p	2.327	1.355	0.155	8.7	51	80
		A_3	1.255	0.728	0.096	7.6	23	64
		B_2	1.562	0.331	0.052	6.4	3	43
Olivier								
2-C	1	A_p	2.098	1.217	0.125	9.7	48	72
		A_3	1.226	0.711	0.079	9.0	25	60
		B_2	0.398	0.231	0.042	5.5	3	33
2-NC	1	A_p	3.287	1.906	0.113	16.9	51	72
		A_3	1.121	0.650	0.055	11.8	18	51
		B_2	0.420	0.241	0.036	6.7	2	27
Richland								
3-C	1	A_p	1.610	0.944	0.090	9.5	36	57
		A_3	0.657	0.381	0.050	7.6	12	50
		B_2	0.470	0.273	0.049	5.6	12	64
3-NC	1	A_p	2.226	1.291	0.116	11.1	56	65
		A_3	0.948	0.550	0.058	9.5	40	79
		B_2	0.454	0.263	0.043	6.1	6	60
4-C	2	A_p	0.959	0.566	0.066	8.6	9	20
		A_3	0.805	0.467	0.054	8.6	1	6
		B_2	0.347	0.201	0.049	4.1	2	17
4-NC	2	A_p	2.090	1.212	0.129	9.4	24	60
		A_3	0.613	0.356	0.052	6.7	1	6
		B_2	0.316	0.183	0.044	4.2	1	9

TABLE 4.–(Continued)

Profile	Area	Horizon	Organic Matter %	Carbon %	Nitrogen %	C:N Ratio	Aggregates >1.00 mm %	Aggregates >0.21 mm %
Richland (continued)								
5-C	2	A_p	0.946	0.549	0.061	9.0	10	22
		A_3	0.695	0.403	0.053	7.6	7	30
		B_2	0.296	0.172	0.045	3.8	1	12
5-NC	2	A_p	1.588	0.875	0.106	8.3	51	73
		A_3	0.722	0.419	0.052	8.1	28	52
		B_2	0.352	0.204	0.038	5.4	2	23
6-C	2	A_p	1.464	0.849	0.104	8.2	10	28
		A_3	0.723	0.419	0.058	7.2	11	41
		B_2	0.341	0.198	0.044	4.5	5	46
6-NC	2	A_p	2.758	1.600	0.165	9.7	31	49
		A_3	0.952	0.552	0.068	8.1	27	54
		B_2	0.353	0.205	0.052	3.9	4	33
7-C	2	A_p	0.827	0.480	0.060	8.0	3	11
		A_3	0.295	0.171	0.034	5.0	1	8
		B_2	0.322	0.187	0.048	3.9	3	42
7-NC	2	A_p	1.153	0.662	0.076	8.7	17	48
		A_3	0.486	0.297	0.042	6.6	4	27
		B_2	0.450	0.253	0.054	4.7	5	42
Lintonia								
8-C	2	A_p	1.174	0.681	0.073	9.3	15	28
		A_3	0.447	0.259	0.037	7.0	2	8
		B_2	0.439	0.255	0.050	5.1	4	38
8-NC	2	A_p	1.452	0.842	0.086	9.8	31	55
		A_3	0.557	0.323	0.034	9.5	2	20
		B_2	0.408	0.237	0.044	5.4	1	8

TABLE 4.—(Continued)

Profile	Area	Horizon	Organic Matter %	Carbon %	Nitrogen %	C:N Ratio	Aggregates >1.00 mm %	Aggregates >0.21 mm %
Lintonia (continued)								
9-C	2	A_p	0.507	0.294	0.038	7.7	5	12
		A_3	0.147	0.085	0.019	4.5	2	6
		B_2	0.194	0.113	0.023	4.9	1	13
9-NC	2	A_p	0.603	0.350	0.042	8.3	37	48
		A_3	0.194	0.113	0.018	6.3	4	10
		B_2	0.214	0.124	0.026	4.8	1	17
Olivier								
10-C	2	A_p	1.253	0.724	0.078	9.3	11	22
		A_3	0.789	0.458	0.061	7.5	5	19
		B_2	0.401	0.233	0.049	4.8	5	22
10-NC	2	A_p	2.236	1.297	0.125	10.4	44	66
		A_3	1.041	0.604	0.074	8.2	22	40
		B_2	0.401	0.233	0.045	5.2	2	19
Richland								
11-C	2	A_p	1.091	0.633	0.070	9.0	2	7
		A_3	1.131	0.656	0.075	8.7	2	7
		B_2	0.416	0.241	0.049	4.9	2	10
11-NC	2	A_p	1.331	0.772	0.087	8.9	37	53
		A_3	0.977	0.567	0.062	9.1	30	42
		B_2	0.319	0.185	0.043	4.3	3	38
12-C	2	A_p	1.135	0.658	0.101	6.5	25	40
		A_3	0.414	0.240	0.076	3.2	7	23
		B_2	0.275	0.160	0.045	3.6	1	20
12-NC	2	A_p	1.456	0.844	0.095	8.9	16	37
		A_3	0.677	0.393	0.057	6.9	2	13
		B_2	0.388	0.225	0.046	4.9	2	28

TABLE 4.—(Continued)

Profile	Area	Horizon	Organic Matter %	Carbon %	Nitrogen %	C:N Ratio	Aggregates >1.00 mm %	Aggregates >0.21 mm %
Richland (continued)								
13-C	2	A_p	1.275	0.740	0.082	9.0	10	23
		A_3	1.040	0.603	0.072	8.4	8	21
		B_2	0.361	0.209	0.047	4.4	1	27
13-NC	2	A_p	1.373	0.796	0.097	8.2	8	21
		A_3	0.364	0.211	0.096	2.2	9	20
		B_2	0.351	0.204	0.046	4.4	3	29
14-C	2	A_p	0.969	0.562	0.062	9.1	12	20
		A_3	0.949	0.550	0.064	8.6	7	23
		B_2	0.371	0.215	0.056	3.8	2	22
14-NC	2	A_p	1.229	0.713	0.084	8.5	45	63
		A_3	0.684	0.397	0.052	7.6	17	32
		B_2	0.438	0.254	0.053	4.8	2	25
15-C	3	A_p	2.375	1.378	0.117	11.8	6	24
		A_3	2.054	1.191	0.108	11.0	5	19
		B_2	1.063	0.617	0.089	6.9	12	60
15-NC	3	A_p	3.084	1.789	0.161	11.1	61	81
		A_3	2.141	1.242	0.111	11.2	40	71
		B_2	1.118	0.648	0.080	8.1	13	63
Olivier								
16-C	3	A_p	2.318	1.344	0.145	9.3	20	54
		A_3	1.491	0.865	0.092	9.4	5	49
		B_2	0.931	0.540	0.077	7.0	3	41
16-NC	3	A_p	2.132	1.237	0.117	10.6	33	72
		A	1.639	0.951	0.099	11.7	13	60
		B	0.994	0.577	0.081	7.1	5	37

TABLE 4.—(Continued)

Profile	Area	Horizon	Organic Matter %	Carbon %	Nitrogen %	C:N Ratio	Aggregates >1.00 mm %	Aggregates >0.21 mm %
Richland								
17-C	3	A_p	1.018	0.590	0.071	8.3	5	13
		A_3	1.001	0.581	0.072	8.1	17	34
		B_2	0.680	0.394	0.055	7.2	8	43
17-NC	3	A_p	2.048	1.188	0.121	9.8	48	61
		A_3	1.069	0.620	0.071	8.7	17	46
		B_2	0.691	0.401	0.058	6.9	8	52
Olivier								
18-C (non-paired)	4	A_p	1.039	0.603	0.079	7.6	7	21
		A_3	0.828	0.480	0.058	8.3	7	19
		B_2	0.520	0.302	0.056	5.4	8	34
19-C (non-paired)	4	A_p	0.873	0.506	0.061	8.3	13	20
		A_3	0.587	0.340	0.053	6.4	13	22
		B_2	0.525	0.305	0.060	5.1	9	38
20-C (non-paired)	4	A_p	0.768	0.445	0.052	8.6	12	20
		A_3	0.699	0.405	0.051	7.9	20	28
		B_2	0.518	0.300	0.055	5.5	11	32
21-C (non-paired)	4	A_p	1.057	0.613	0.083	7.4	10	19
		A_3	0.927	0.538	0.069	7.8	12	23
		B_2	0.555	0.322	0.054	6.0	11	37
22-C	4	A_p	1.060	0.615	0.076	8.1	8	25
		A_3	1.103	0.640	0.075	8.5	7	21
		B_2	0.393	0.228	0.045	5.1	6	24
22-NC	4	A_p	1.037	0.601	0.066	9.1	31	46
		A_3	0.907	0.526	0.060	8.8	24	36
		B_2	0.482	0.280	0.051	5.5	9	31

TABLE 5.—Cation Exchange Capacity, Exchangeable Bases, Base Saturation and pH of A_p Horizons in Pleistocene Terrace Soils

Profile	Area	C.E.C.	Ca.	Mg.	K	Na	Calcium Saturation %	Base Saturation %	pH
		m.e./100 g. Soil							
Lintonia									
1-C	1	5.0	1.4	0.5	0.26	0.06	28	45	5.1
1-NC		11.1	1.4	1.0	0.19	0.25	13	26	4.8
Olivier									
2-C	1	8.3	2.9	1.8	0.27	0.07	35	61	6.2
2-NC		10.6	2.5	0.7	0.23	0.08	24	34	5.1
Richland									
3-C	1	5.4	2.1	1.4	0.17	0.06	39	69	6.8
3-NC		7.6	1.9	0.8	0.22	0.08	25	39	5.2
4-C	2	6.1	2.6	1.0	0.33	0.06	43	66	5.7
4-NC		10.4	4.9	1.1	0.67	0.06	47	65	6.2
5-C	2	4.6	1.8	0.6	0.27	0.09	39	60	6.4
5-NC		8.2	4.5	0.9	0.55	0.07	55	73	6.5
6-C	2	7.2	1.7	0.7	0.45	0.08	24	41	4.9
6-NC		9.8	3.2	0.9	0.27	0.08	33	56	5.6
7-C	2	5.2	1.3	0.5	0.44	0.06	25	44	4.9
7-NC		6.3	3.3	1.2	0.45	0.08	52	80	6.7
Lintonia									
8-C	2	4.8	3.1	0.4	0.31	0.04	65	80	6.5
8-NC		6.1	2.4	0.6	0.58	0.04	39	59	5.8
9-C	2	4.0	1.6	0.5	0.13	0.04	40	57	5.3
9-NC		3.7	1.4	0.5	0.15	0.04	38	56	5.4
Olivier									
10-C	2	8.1	2.7	0.9	0.22	0.17	33	49	5.8
10-NC		10.6	4.4	1.4	0.33	0.06	42	58	5.8
Richland									
11-C	2	8.5	6.9	0.7	0.62	0.07	81	96	6.8
11-NC		6.8	2.9	0.8	0.17	0.07	43	58	6.0
12-C	2	8.0	4.3	1.7	0.57	0.16	54	84	6.8
12-NC		7.9	3.2	1.3	0.44	0.08	41	64	6.5
13-C	2	7.2	3.6	1.6	0.52	0.12	50	81	6.7
13-NC		8.4	3.3	1.5	0.52	0.12	39	65	5.6
14-C	2	5.6	3.6	0.6	0.19	0.10	64	80	6.6
14-NC		6.2	2.4	0.7	0.37	0.07	39	57	6.1
15-C	3	10.9	3.1	0.8	0.28	0.07	28	39	5.1
15-NC		11.4	2.9	0.9	0.35	0.07	25	37	5.2
Olivier									
16-C	3	10.5	1.8	0.7	0.31	0.08	17	28	4.9
16-NC		10.4	2.1	1.0	0.12	0.09	20	32	4.9
Richland									
17-C	3	9.3	2.4	1.1	0.21	0.10	26	41	5.0
17-NC		10.6	6.4	1.3	0.17	0.10	60	75	6.1

TABLE 5.—(Continued)

Profile	Area	C.E.C.	Ca.	Mg.	K	Na	Calcium Saturation %	Base Saturation %	pH
		m.e./100 g. Soil							
Olivier									
18-C	4	5.8	2.5	0.8	0.17	0.06	43	61	6.1
19-C	4	5.9	1.7	1.1	0.20	0.09	29	52	5.4
20-C	4	5.4	1.8	1.2	0.11	0.15	33	60	5.9
21-C	4	7.4	2.8	1.5	0.22	0.10	38	62	5.7
22-C	4	6.0	2.9	1.7	0.11	0.10	48	80	6.7
22-NC		6.9	2.7	1.4	0.15	0.10	39	63	5.9

noncultivated to 8.6 per cent in the cultivated soils, while aggregates greater than 0.21 mm. decreased from 40.2 per cent in the noncultivated to 26.3 per cent in the cultivated soils. The relative differences in aggregation in the A_3 horizons were of about the same magnitude as those in the A_p horizons. No appreciable differences in aggregation existed between the cultivated and noncultivated soils in the B_2 horizons.

Data presented in Table 6 also show that average organic matter contents of the noncultivated soils were 1.856, 0.908, and 0.539 per cent for the A_p, A_3, and B_2 horizons, respectively. The average organic matter contents of the cultivated soils were 1.305, 0.869, and 0.453 per cent for the A_p, A_3, and B_2 horizons, respectively. In both the cultivated and noncultivated soils, the organic matter content decreased rather uniformily with increased depth in the profile. The greatest differences in the organic matter content between the cultivated and noncultivated soils occurred in the A_p horizons. The cultivated soils contained 70 per cent as much organic matter as the non-cultivated soils in the A_p, 96 per cent as much organic matter in the A_3, and 84 per cent as much organic matter in the B_2 horizon.

The decreases in organic matter due to continuous cultivation were not nearly as great, percentage-wise, as the decreases that occurred in aggregation. Organic matter was an important factor in determining soil aggregation. The fairly close association between organic matter and aggregation for all of the A_p horizons is illustrated in Figure 1. An examination of this figure shows that increases in organic matter from 1 per cent to 2 per cent were a little more effective in promoting aggregation than were increases in organic matter beyond the 2 per cent level. When the data showing the relationship between aggregation and organic matter for the surface horizons of all the soils are divided between the cultivated soils and the noncultivated soils, as has been done in Figures 2 and 3, several conclusions are apparent. Most of the soils with low aggregation and low organic matter contents were in cultivation whereas most of those with high aggregation and high organic matter contents were noncultivated. Also, the slopes of the equa-

TABLE 6.—Physical and Chemical Properties of Pleistocene Terrace Soils by Horizons

	Aggregates									
	>1.00 mm %	>0.21 mm %	O.M. %	N %	C:N Ratio	Sand %	Silt %	Clay %	Free Fe_2O_3 %	Concretions >0.21 mm %
CULTIVATED										
A_p Horizons	14.5	29.1	1.305	0.084	8.87	15.35	69.96	14.69	1.97	5.05
A_3 Horizons	8.6	26.3	0.869	0.063	7.62	12.30	70.01	17.81	2.41	4.14
B_2 Horizons	4.2	32.6	0.453	0.051	4.99	9.43	59.28	31.20	4.48	3.41
NONCULTIVATED										
A_p Horizons	37.3	58.3	1.856	0.108	9.80	13.29	72.48	14.23	2.03	3.93
A_3 Horizons	17.8	40.2	0.908	0.064	8.26	11.80	68.66	17.81	2.42	3.04
B_2 Horizons	4.0	32.4	0.539	0.050	5.49	8.89	61.43	29.58	4.31	2.39

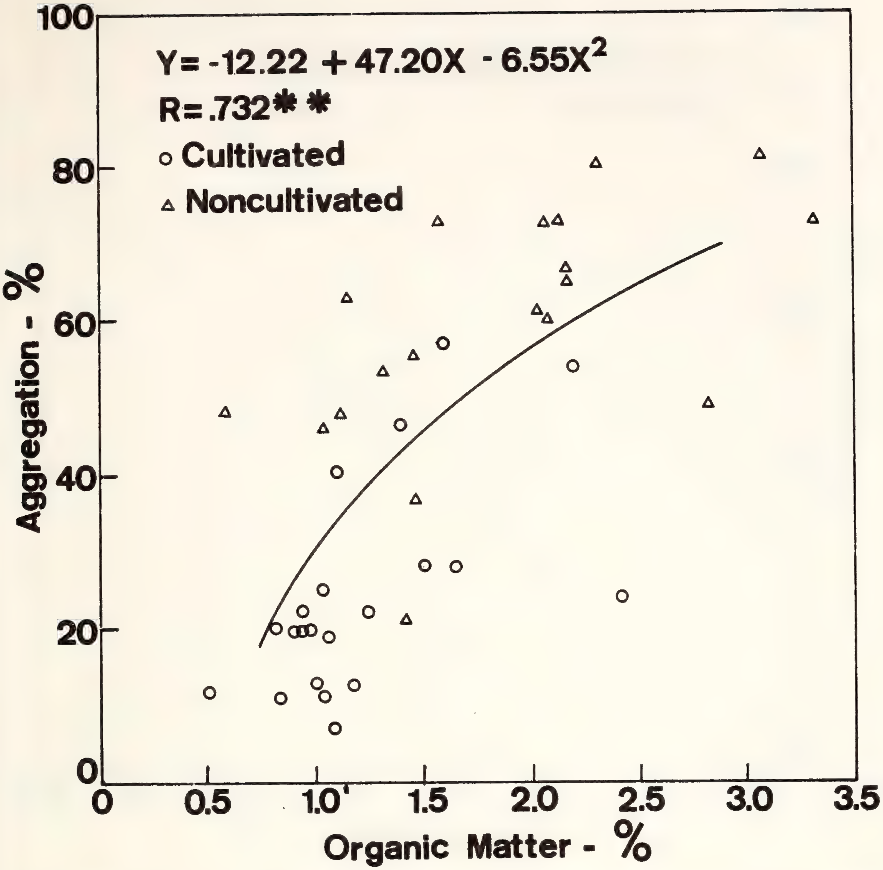

FIGURE 1.—Relationship between per cent aggregates greater than 0.21 mm. and per cent organic matter for all A_p horizons.

tions relating aggregation to organic matter for the noncultivated soils and the cultivated soils indicate the greater effect of organic matter on aggregation at low organic-matter levels.

The relationship between aggregation and the organic matter-clay ratio in the A_p horizons of all the soils studied on the Macon Ridge is shown in Figure 4. An increase in the ratio of organic matter to clay resulted in a decided improvement in aggregation. The data show an aggregation of approximately 15 per cent at an organic matter-clay ratio of 0.05 and an aggregation of approximately 60 per cent at an organic matter-clay ratio of 0.15. Sturgis (*41*) has recently suggested the necessity of an organic matter-clay ratio of .08 in order for adequate structure to be maintained. On the basis of the data presented here, this would result in an aggregation of approximately 25 per cent.

When the data for all A_3 horizons were combined, there was a

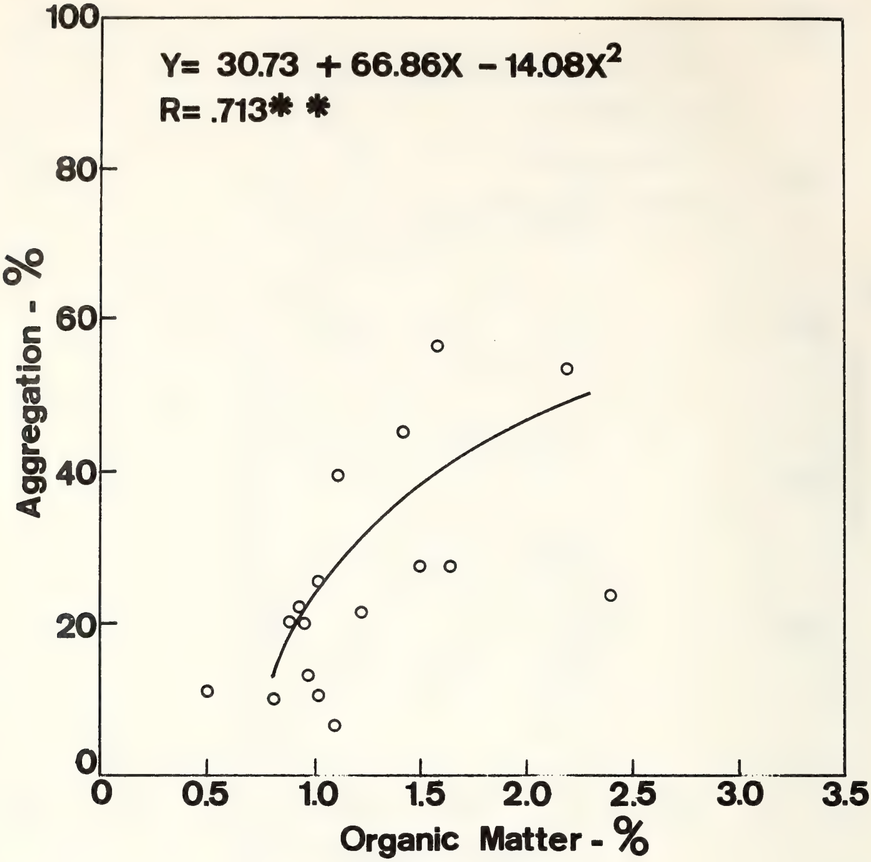

FIGURE 2.—Relationship between per cent aggregates greater than 0.21 mm. and per cent organic matter for all cultivated A_p horizons.

significant relationship between aggregation and organic matter content, as is shown in Figure 5.

Although a positive relationship existed between organic matter and aggregation in the cultivated A_3 horizons, as is shown in Figure 6, the correlation coefficient was not significant.

As is shown by the curvilinear regression line in Figure 7, the correlation coefficient between organic matter and aggregation was highly significant in the noncultivated A_3 horizons. Above the 1 per cent organic-matter level there was a tendency for increment increases in organic matter to become progressively less effective as a positive factor on aggregation.

The curvilinear regression line in Figure 8 indicates that organic matter levels above 1 per cent had little influence on aggregation in the B_2 horizons.

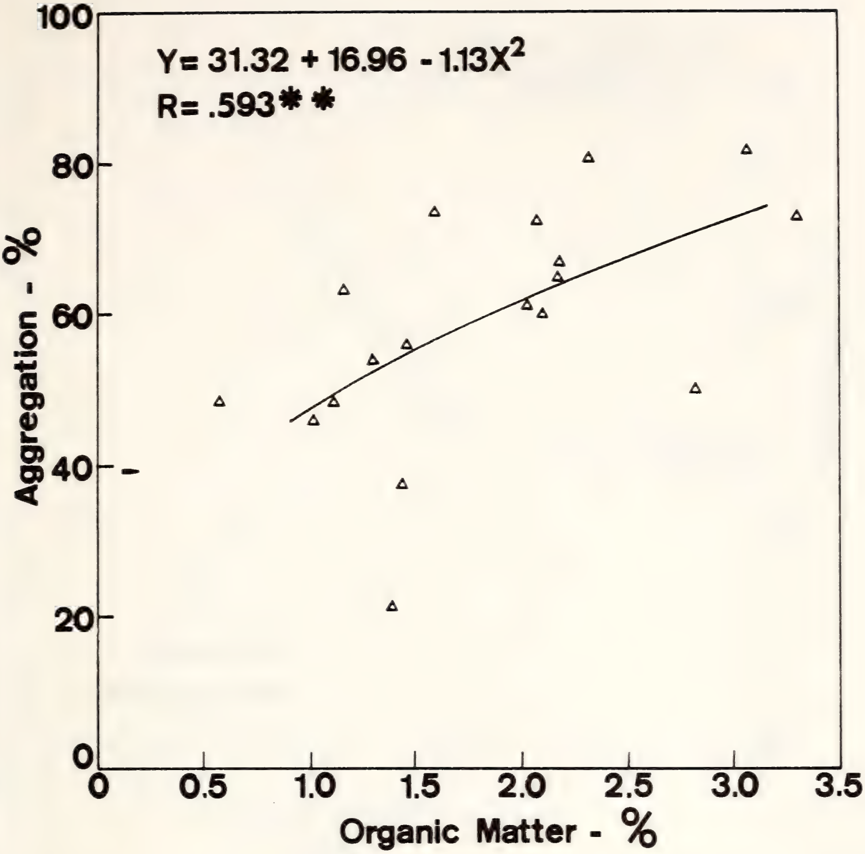

FIGURE 3.—Relationship between per cent aggregates greater than 0.21 mm. and per cent organic matter for all noncultivated A_p horizons.

It may be noted in Table 6 that the carbon-nitrogen ratio in the cultivated soils was narrower than in the noncultivated soils, and the carbon-nitrogen ratio became narrower with increase in depth in the profile. The average carbon-nitrogen ratios in the cultivated soils was 8.87 in the A_p, 7.62 in the A_3, and 4.99 in the B_2 horizon. In the noncultivated soils the ratios were 9.80, 8.26, and 5.49 for the A_p, A_3, and B_2 horizons, respectively.

The average clay contents of the cultivated and noncultivated soils were almost identical. The averages were about 14 per cent for the A_p horizons, 18 per cent for the A_3 horizons, and 30 percent for the B_2 horizons. Aggregation did not appear to be closely related to clay content in these soils. In only the A_p horizon was there a significant correlation between clay content and aggregation. In this correlation, clay could account for only about 10 per cent of the variation in aggregation.

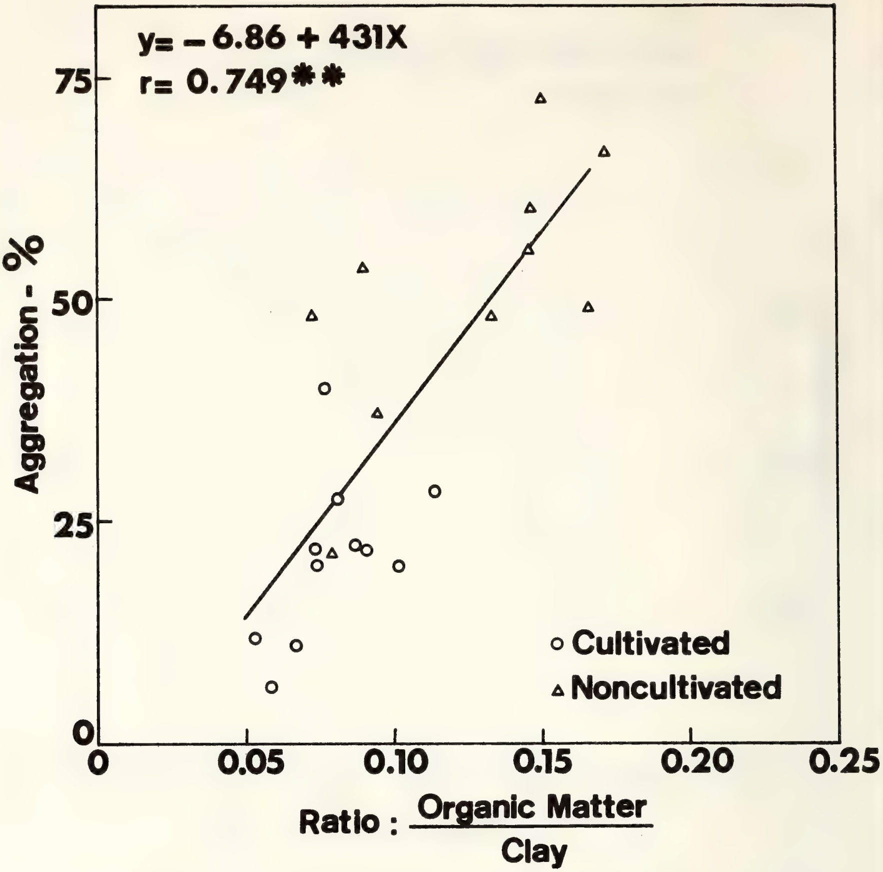

FIGURE 4.—Relationship between per cent aggregates greater than 0.21 mm. and organic matter-clay ratio for all A_p horizons on the Macon Ridge.

One cause of this lack of relationship was the low variation in clay content among the various soils. Almost all of the soils had clay contents that ranged from 8 to 18 per cent in the A_p horizon.

The curvilinear regression line in Figure 9 shows that the organic matter content increased significantly with increase in clay content in the A_p horizons. However, this relationship tended to become less marked as the clay content increased.

The free iron oxide content was essentially the same in the cultivated and noncultivated soils. The content of free iron oxide, as shown in Table 6, averaged about 2.0 per cent in the A_p, 2.4 per cent in the A_3, and 4.4 per cent in the B_2 horizons. Free iron oxide appeared to be closely related to clay content.

The average cation exchange capacity of the noncultivated A_p horizons was 8.5 m.e. per 100 grams of soil as compared with an average of

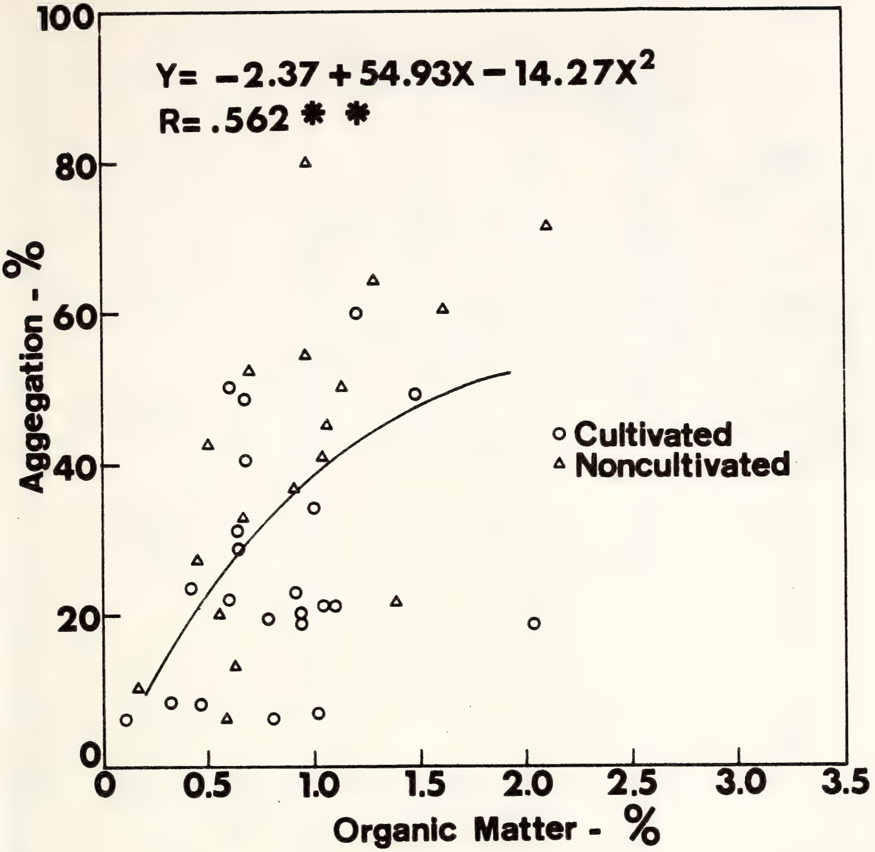

FIGURE 5.—Relationship between per cent aggregates greater than 0.21 mm. and per cent organic matter for all A_3 horizons.

6.9 m.e. in the cultivated soils. These values are reported in Table 7. This difference can probably be accounted for by the difference of 0.551 per cent that existed between the organic matter contents of these soils, since the clay contents of the cultivated and noncultivated soils were almost identical. If the difference in cation exchange capacity of 1.6 m.e. is attributed to the difference in organic matter content, then each one per cent organic matter would account for about 2.9 m.e. of exchange capacity per 100 grams of soil. The organic matter content of these soils makes an important contribution to their cation exchange capacity. The relationship between cation exchange capacity and organic matter content was highly significant, as is shown in Figure 10.

Comparisons of the average contents of calcium, magnesium, potassium and sodium, the per cent saturation by each of these elements, and total base saturation, are reported in Table 7. The cultivated soils were

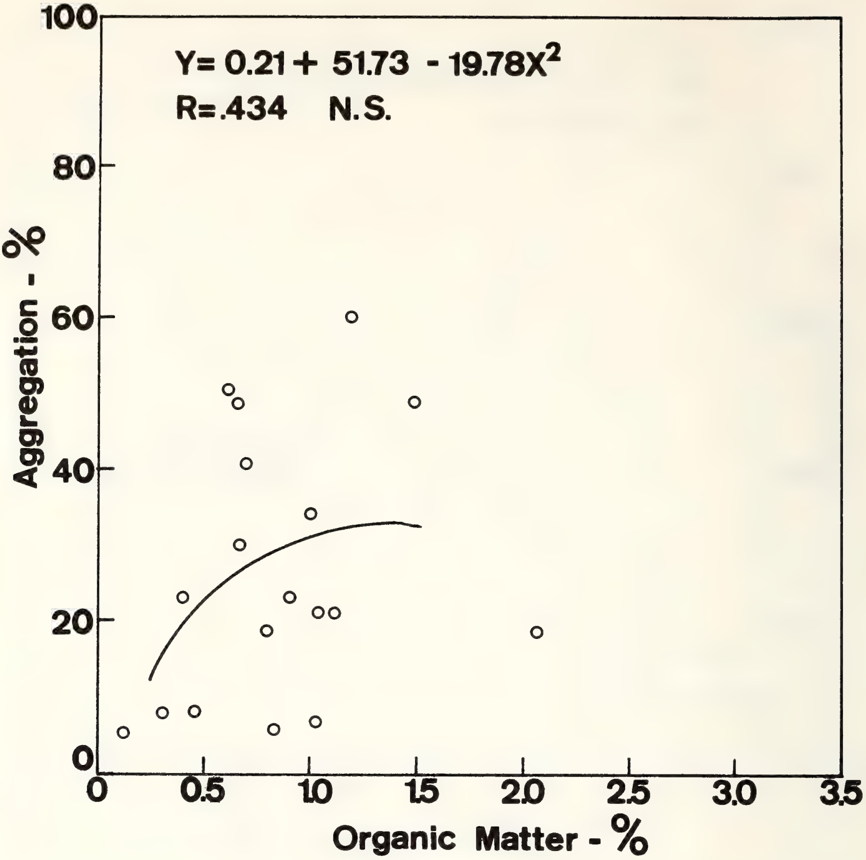

FIGURE 6.—Relationship between per cent aggregates greater than 0.21 mm. and per cent organic matter for all cultivated A_3 horizons.

slightly lower than the noncultivated soils in most of the bases that were determined, but because of a lower cation exchange capacity, were higher in per cent base saturation.

Considerable variation in physical and chemical properties existed in the A_p horizons among the four areas of the state from which the soil samples were taken. The means of the results of analyses on A_p horizons for each of the areas are presented in Tables 8 and 9. The primary reason the East Baton Rouge samples showed a lower average content of organic matter and aggregation is that at that location four of the six profiles sampled were nonpaired cultivated soils.

The means of the results of physical and chemical analyses on each horizon in the profiles at cultivated sites are shown for each of the three soil series in Table 10.

The means of the analytical results on 16 samples of cultivated and

TABLE 7.—Cation Exchange Capacity, Exchangeable Bases and Base Saturation for all A_p Horizons

	C.E.C.	Ca	Mg	K	Na	Saturation				
						Ca	Mg	K	Na	Base
A_p Horizons	m.e./100 g. Soil					%	%	%	%	%
Cultivated	6.9	2.8	0.9	0.29	0.09	40.6	13.0	4.2	1.3	59.1
Noncultivated	8.5	3.1	1.0	0.33	0.09	36.5	11.8	3.9	1.1	53.2

TABLE 8.—Chemical and Physical Properties of A_p Horizons of Pleistocene Terrace Soils by Sample Areas

	Aggregates									
Area	>1.00 mm %	>0.21 mm %	O.M. %	N %	C:N Ratio	Sand %	Silt %	Clay %	Free Fe_2O_3 %	Concretions >0.21 mm %
East Feliciana	44.7	65.3	2.160	0.115	10.84	23.65	58.33	18.02	2.35	13.27
Macon Ridge	20.6	36.6	1.312	0.086	8.76	13.15	73.68	13.17	1.88	2.81
Opelousas Ridge	28.3	50.8	2.163	0.122	10.15	8.98	73.57	17.45	2.21	0.93
East Baton Rouge	13.5	25.2	0.972	0.070	8.18	11.93	77.55	10.52	1.90	3.77

TABLE 9.—Cation Exchange Capacity, Exchangeable Bases and Base Saturation for All A_p Horizons by Sample Areas

	C.E.C.	Ca	Mg	K	Na	Saturation				
						Ca	Mg	K	Na	Base
Area	m.e./100 g. Soil					%	%	%	%	%
East Feliciana	8.0	2.0	1.0	0.22	0.10	25.0	12.5	2.8	1.3	41.5
Macon Ridge	7.0	3.1	0.9	0.39	0.08	44.3	12.9	5.6	1.1	63.9
Opelousas Ridge	10.5	3.1	1.0	0.24	0.09	29.5	9.5	2.3	0.9	42.2
East Baton Rouge	6.2	2.4	1.3	0.16	0.10	38.7	21.0	2.6	1.6	64.0

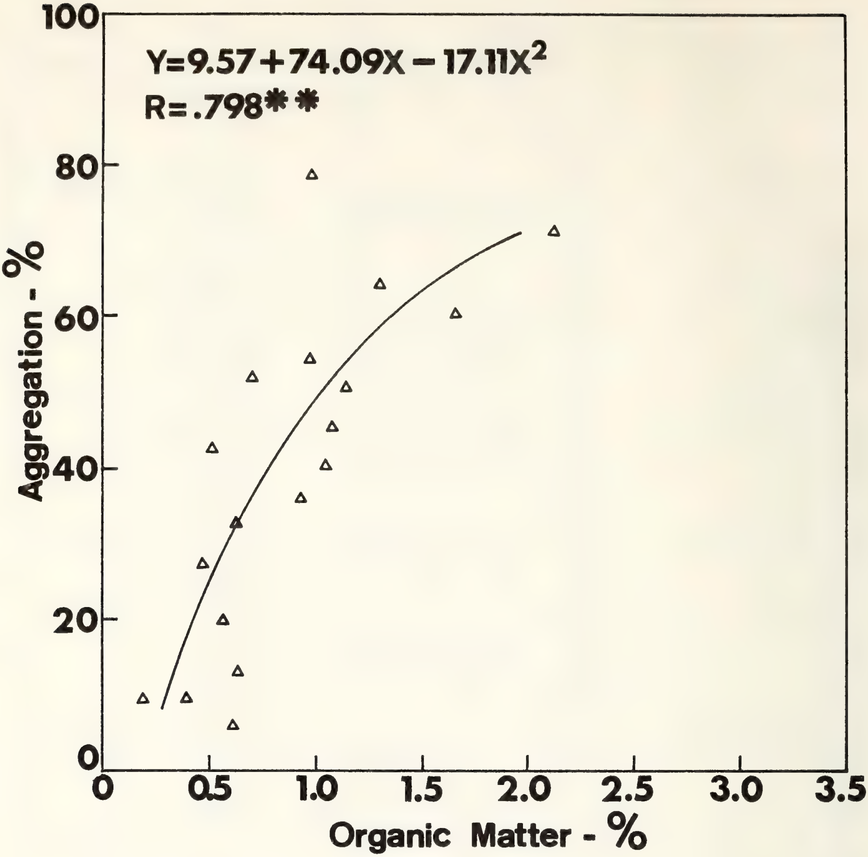

FIGURE 7.—Relationship between per cent aggregates greater than 0.21 mm. and per cent organic matter for all noncultivated A_3 horizons.

TABLE 10.—Physical and Chemical Characteristics of Cultivated Lintonia, Richland, and Olivier Soils

Soil	Horizon	Aggregates >1.00 mm %	Aggregates >0.21 mm %	O.M. %	Clay %	C.E.C. m.e.*	Base Saturation %
Lintonia	A_p	15	29	1.031	10.5	4.6	61
(3 samples)	A_3	12	21	0.426	16.4		
	B_2	3	34	0.364	32.0		
Richland	A_p	12	24	1.243	14.8	7.1	64
(11 samples)	A_3	7	24	0.888	18.7		
	B_2	4	33	0.449	33.1		
Olivier	A_p	16	35	1.308	14.3	7.2	57
(8 samples)	A_3	12	40	0.956	15.8		
	B_2	7	43	0.530	27.2		

*Milliequivalents per 100 grams of soil.

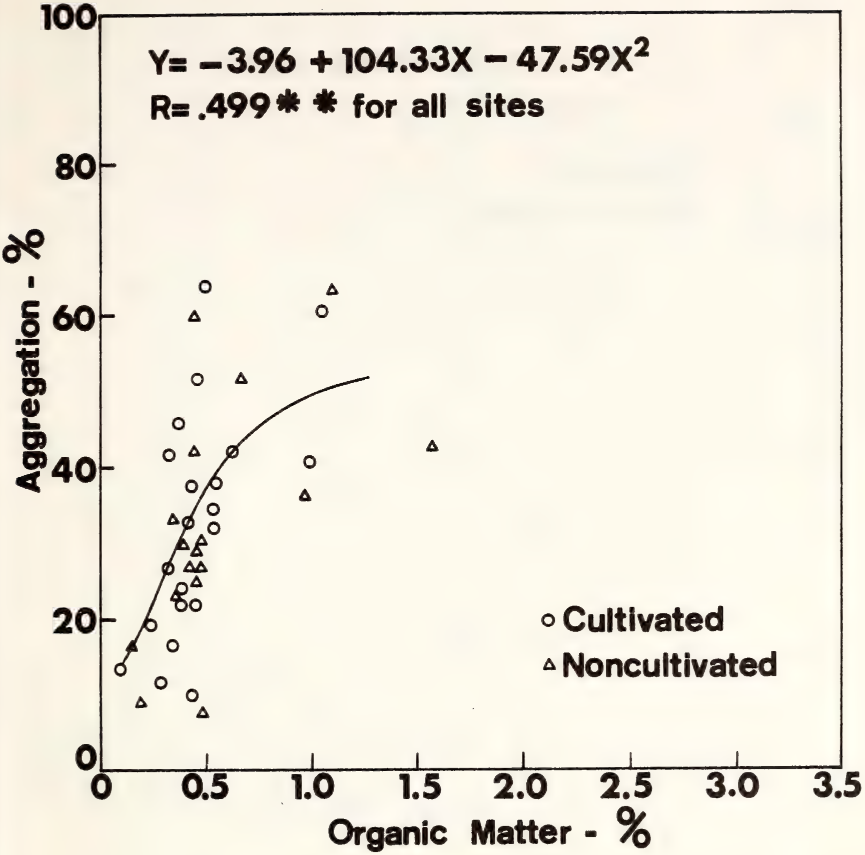

FIGURE 8.—Relationship between per cent aggregates greater than 0.21 mm. and per cent organic matter for all B_2 horizons.

noncultivated Richland soil on the Macon Ridge are reported by horizons in Table 11.

The results of X-ray diffraction analyses on the A_p and B_2 horizons of six of the soil profiles studied are shown in Table 12. It may be noted that horizons of both of the soil profiles from near Youngsville, Louisiana, on the Opelousas Ridge, contained montmorillonite clay. There was over 40 per cent montmorillonite in the colloidal fraction of the B_2 horizon of an Olivier profile and of the A_p and B_2 of a Richland profile. Montmorillonite did not occur in any of the horizons analyzed from the Macon Ridge or Baton Rouge areas.

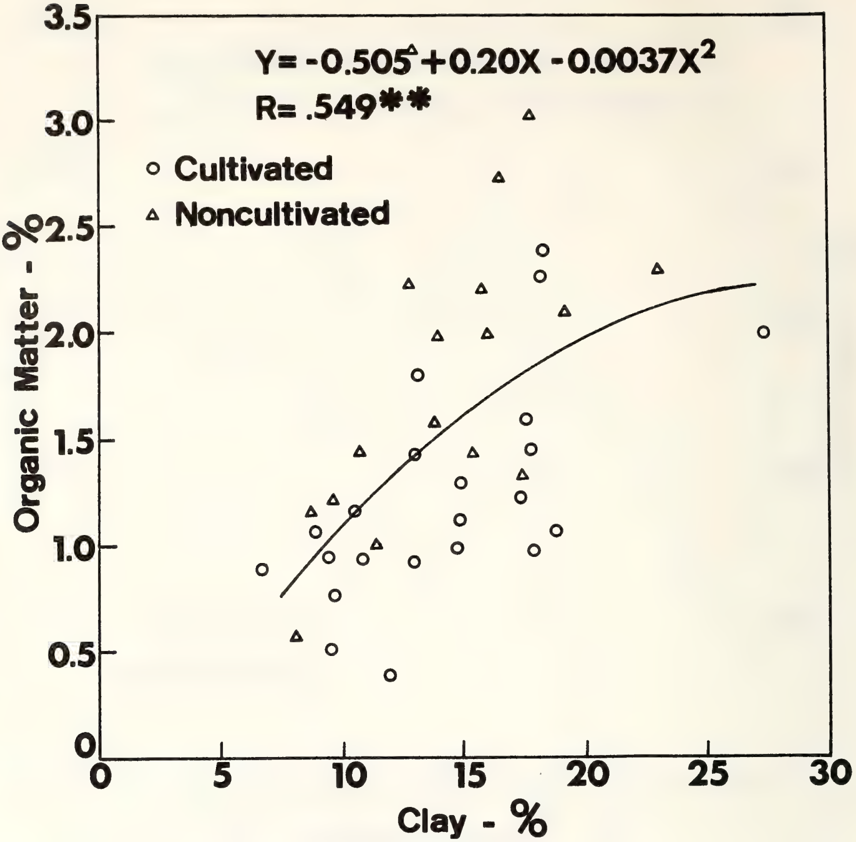

FIGURE 9.—Relationship between per cent organic matter and per cent clay for all A_p horizons.

TABLE 11.—Physical and Chemical Characteristics of Sixteen Samples of Richland Soil on the Macon Ridge

		Aggregates					
Land Use	Horizon	>1.00 mm %	>0.21 mm %	O.M. %	Clay %	C.E.C. m.e.*	Base Saturation %
Cultivated	A_p	10.1	21.4	1.082	13.9	6.6	69
	A_3	5.5	19.9	0.757	18.2		
	B_2	2.1	24.5	0.341	34.6		
Noncultivated	A_p	28.6	50.1	1.622	13.8	8.0	65
	A_3	13.5	30.1	0.768	18.8		
	B_2	2.8	28.4	0.371	34.0		

*Milliequivalents per 100 grams of soil.

TABLE 12.—Results of X-ray Diffraction Analyses of Samples of the A_p and B_2 Horizons of Six Profiles of the Mississippi River Terrace Soils

Profile	Area	Series	Horizon	Depth	Inorganic Colloidal Material
8-C*	2	Lintonia	A_p	0-7”	Illite, 10-40%; kaolinite, 10-40%; quartz, 0-10%; interstratified, (?), primarily poorly ordered hydrated micas.
			B_2	17-22”	Same as A_p horizon.
10-C	2	Olivier	A_p	0-5”	Chlorite/vermiculite interstratified, over 40%; kaolinite, 10-40%; illite, 0-10%; quartz, 0-10%.
			B_2	16-19”	Illite, 10-40%; kaolinite, 10-40%; interstratified, (?), primarily poorly ordered hydrated micas.
12-NC*	2	Richland	A_p	1-5”	Chlorite/vermiculite interstratified, over 40%; kaolinite, 10-40%; illite, 0-10%; quartz, 0-10%.
			B_2	16-20”	Illite, 10-40%; kaolinite, 10-40%; quartz, 0-10%; interstratified, (?), primarily poorly ordered hydrated micas.
16-C	3	Olivier	A_p	0-6”	Illite, 10-40%; kaolinite, 10-40%; quartz 0-10%; interstratified, (?), primarily poorly ordered hydrated micas.
			B_2	15-19”	Montmorillonite, over 40%; illite, 10-40%; kaolinite, 10-40%; quartz, 0-10%.
17-C	3	Richland	A_p	0-6”	Montmorillonite, over 40%; illite, 10-40%; kaolinite, 10-40%; quartz, 0-10%.
			B_2	14-18”	Same as A_p horizon.
18-C	4	Olivier	A_p	0-5”	Illite, 10-40%; kaolinite, 10-40%; quartz, 0-10%; interstratified, (?), primarily poorly ordered hydrated micas.
			B_2	8-16”	Same as A_p horizon.

*C—cultivated; NC—noncultivated.

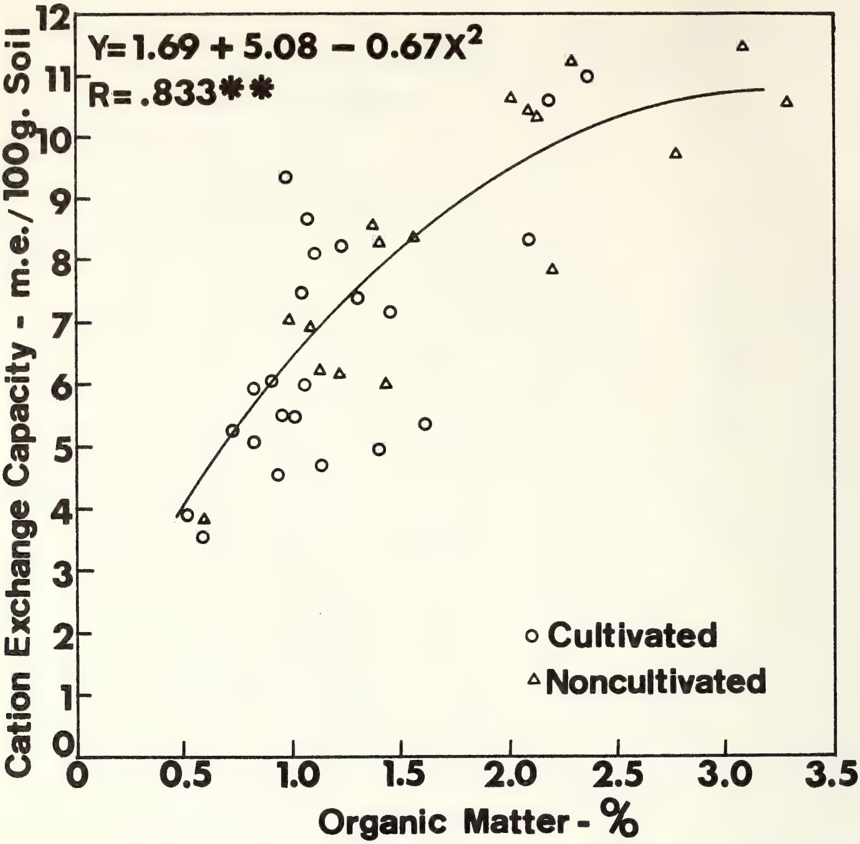

FIGURE 10.–Relationship between cation exchange capacity and per cent organic matter for all A_p horizons.

Summary and Conclusions

The results of physical and chemical analyses on bulk soil samples of three horizons of 40 soil profiles of the Mississippi River terrace soils in Louisiana are presented. The soils analyzed were the three most important soils of the Pleistocene-Mississippi River terraces: the Lintonia (Memphis) series, the Richland (Loring) series and the Olivier series. In most cases paired cultivated-noncultivated samples of the same profile were analyzed. Various physical and chemical determinations were made on the A_p, A_3 and B_2 horizons of each profile. The influence of the various factors on aggregation in these soils was then determined.

Linear or curvilinear regression analyses were run for comparisons that were statistically correlated.

The per cent aggregates greater than 1 mm. in diameter decreased with increase in depth in both the cultivated and noncultivated soils. Aggregates greater than 0.21 mm. decreased with increase in depth in the noncultivated soils but remained fairly constant throughout the profile of the cultivated soils.

Compared with cultivated surface soils, noncultivated surface soils contained 61 per cent more aggregates greater than 1 mm., and 50 per cent more aggregates greater than 0.21 mm.

The average organic matter content of the noncultivated soils was 30 per cent higher in the A_p, 4 per cent higher in the A_3, and 16 per cent higher in the B_2 horizon, than in the cultivated soils. Organic matter was the most important factor contributing to the water-stable aggregate content of the soils.

Curvilinear regression analyses indicated that above the 2 per cent organic-matter level in the A_p and A_3 horizons, increases in organic matter content became progressively less associated with aggregation. Maximum aggregation appeared to be reached in the B_2 horizon at an organic matter level of about one per cent.

The carbon-nitrogen ratio became narrower with increase in depth in the profile, and was narrower in the cultivated than in the noncultivated soils.

One per cent organic matter contributed about 2.9 m. e. to the cation exchange capacity of the soils.

Organic matter increased significantly with increases in the clay content in the A_p horizon.

Aggregation was significantly correlated with clay content only in the A_p horizon of the cultivated soils.

A positive relationship existed between aggregation and the organic matter-clay ratio. Soils with organic matter-clay ratios higher than 0.1 per cent organic matter per 1 per cent clay had aggregations of 30 per cent or higher. This degree of aggregation appears to be the minimum necessary for desirable structure in the medium textured soils included in this study.

A highly significant correlation existed between clay and free iron oxides in all soils and all horizons.

Soil pH generally decreased with increase in depth in the profiles.

X-ray diffraction analyses of horizons in six soil profiles studied showed that the inorganic colloid fraction of some of the horizons on the Opelousas Ridge was over 40 per cent montmorillonite clay. No montmorillonite was detected in the other soil samples analyzed.

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Cotton Seedling Diseases And Their Control

James B. Sinclair

Louisiana State University and
Agricultural and Mechanical College
Agricultural Experiment Station
Doyle Chambers, Director

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Recommendations for Seedling Disease Control

1. KNOW YOUR PROBLEMS. There are several ways in which losses due to cotton seedling diseases can be reduced or eliminated. Be sure to know the cause of not getting and keeping a stand of cotton.

2. CROP ROTATION is necessary to prevent the build-up of certain cotton disease organisms in the soil. Where feasible, allow at least two years or longer between plantings of cotton on the same land. Select only fertile, well-drained, and warm-natured soils.

3. PREPARE SEEDBEDS early so crop residues can be disposed of properly. Deep plowing of cotton land may be desirable to break up hard pans and allow deeper penetration of cotton roots.

4. CHOOSE QUALITY SEED. Use the highest quality seed available. Know the origin and at least the percentage germination of cottonseed to be used for planting.

5. PLANT ONLY TREATED SEED. Use only treated cottonseed to help reduce losses from seed- and soil-borne disease organisms.

6. ONLY WHEN SOIL TEMPERATURES are high enough to give rapid germination and growth of seedlings should cottonseed be planted.

7. MAKE SURE that other factors, such as nutritional difficulties, nematodes, insects, and mechanical injuries, are not involved in stand losses.

8. USE SOIL FUNGICIDES at the time of planting *only* if a history of seedling disease due to soil-borne pathogens is known. Only certain fields and areas within fields may need to be treated. The use of a soil fungicide is good insurance for getting and holding a stand of cotton from the first planting where seedling diseases are a problem.

9. EARLY CROP RESIDUE DISPOSAL. Destroy cotton stalks immediately after harvest. This practice will reduce the amount of carryover of certain cotton disease-causing organisms.

Cotton Seedling Diseases and Their Control

JAMES B. SINCLAIR
Associate Professor of Botany and Plant Pathology

Introduction

The purpose of this publication is to provide Louisiana county agents and cotton growers with the theory and practice of controlling the cotton seedling disease complex and to summarize research on cotton seedling diseases conducted by personnel of Louisiana Agricultural Experiment Station. Most of the research has been directed toward understanding and controlling cotton soreshin, caused by *Rhizoctonia solani* Kühn (*3*).[1] These data plus information from other workers are brought together to provide an up-to-date account of methods and materials involved in a program of controlling cotton seedling diseases for Louisiana.

I. The Problem of Cotton Seedling Diseases

Cotton seedling diseases are not new. The first report of *Rhizoctonia* sp. causing soreshin on cotton was made in 1895 by Atkinson (*3*) in Alabama. Edgerton (*31*) described the disease on Louisiana cotton in 1911. Only within the last decade, with costs of production increasing and profits decreasing, has the economic importance of soreshin and other seedling diseases of cotton gained recognition.

Losses due to cotton seedling diseases have led the list of estimated

TABLE 1.—Estimated annual losses, in per cent of cotton yield, as a result of disease damage in Louisiana for year indicated

Disease	Year[1] 1961	1962	1963	1964
Seedling diseases	5.0	5.0	5.0	5.0
Nematodes	1.0	4.0	5.0	5.0
Fusarium wilt	3.5	5.0	3.0	5.0
Verticillium wilt	1.0	1.0	1.0	0.5
Boll rots	5.0	10.0	1.0	30.0
Bacterial blight	Trace	0.5	Trace	Trace
Anthracnose	Trace	Trace	Trace	Trace
Ascochyta blight	Trace	Trace	Trace	Trace
Root rot	Trace	Trace	Trace	Trace
Total per cent loss	15.5	25.5	15.0	45.5

[1] 1963 and 1964 estimates by J. A. Pinckard.

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[1] Italic numbers in parentheses refer to Literature Cited, pages 33-35.

annual losses in cotton yield as a result of disease damage in Louisiana for the past 4 years (Table 1). Louisiana growers are not alone in this problem. Growers in Arkansas, Mississippi, Texas, and other cotton growing states suffer similar losses (*21, 22, 23, 24, 27, 30, 33, 54*). In 1961, 1963, and 1964 personnel of the Louisiana Agricultural Extension Service cooperated with the author in estimating per cent cotton acres

TABLE 2.—Summary on occurrence of cotton seedling diseases and use of soil fungicides for control of cotton seedling diseases, based on questionnaires completed by county agents in 1961, 1963, and 1964. (Approximate number of acres planted are given for 1963 and 1964.)

	Approx. No. acres planted		Per cent acres					
			Affected			Treated		
Parish	1963	1964	1961	1963	1964	1961	1963	1964
Acadia	10,000	11,000		25	60		5	1
Avoyelles	25,000	22,000	10	50	75	3	25	5
Bossier	20,000	18,000	100	75	60	25	30	35
Caddo	32,500	33,000	0	95	75	6	4	5
Caldwell	9,000			50			60	
Catahoula			65			35		
Claiborne	1,750	1,400	20	0	5	0	0	0
Concordia		9,700		60	15	3		20
De Soto		4,000		20	40	0		5
East B.R.	575			0			0	
E. Carroll	31,000	31,000	20	100	25	13	80	65
E. Feliciana	1,300	1,200		18	10		0	0
Evangeline	16,500	14,500	10	5	25	5	2	2
Franklin	60,000	60,000	90	20	40	6	8	10
Grant	4,636			50			30	
Iberia	400	400	10	0	20	0	0	0
Madison	23,000	23,000	95	2	10	50	40	50
Morehouse	35,000	34,000	80	90	100	40	65	20
Natchitoches	21,848		75		20	10	4	0
Ouachita		15,000	65		20	10		10
Pointe Coupee	8,000	8,000	80	50	50	20	37	30
Rapides	20,729		100	100		18	25	
Red River		10,200			15			45
Richland	50,600	53,981	60	40	75	5	15	5
St. Helena	500			10	0		0	0
St. Landry	34,500	34,000	25	10	20	10	5	15
Tangipahoa		600			10			0
Tensas	21,995	22,000	50	55	80	70	23	20
Union	3,300	2,700		10	2		0	0
Vermilion		3,000			50			0
Washington		3,000			15			0
Webster	2,500	2,500		0	0		0	0
W. Carroll	27,000	28,000	75	3	50	8	2	10
W. Feliciana	40			15			0	
Winn			100			25		
Other			35			18		
Total	461,673	446,181						
Ave. per cent			51	35	35	15	18	13

affected with seedling diseases (Table 2). Estimated losses, based on these figures and on observations of plant pathologists, ranged from 2 to 5 per cent of the potential yield in severely affected areas. Any individual grower may lose the equivalent of ¼ to ½ bale per acre due to cotton seedling diseases when all factors (Fig. 1) are considered. In 1963, it was estimated that Louisiana cotton growers had a state-wide loss from these diseases of 5 per cent of potential yield, or about $6 million. In 1964 the estimated loss amounted to about $4 million. These estimates were based not only on number of plants lost to disease, but also on additional costs incurred because of an uneven, skippy stand and replanting. There are many factors in cotton production that are directly or indirectly influenced by seedling diseases (Fig. 1). Some of these factors include fertilizer use and costs, insect control, weed control, harvesting, and control of other cotton diseases. Studies for three years on three-quarter acre plots at the Northeast Louisiana Agricultural Experiment Station, St. Joseph, have shown that yield from replanted cotton has been consistently below that of nonreplanted cotton and cotton from soil treated with various fungicides (Table 3). The assurance of getting and keeping a uniform stand of cotton at first planting is one of the last problems to be solved before complete mechanization of cotton production can be realized.

Did You Have to Make This Choice Last Year?

Poor Stand Due to Seedling Diseases

Replanting

- Additional seed
- Additional wages
- Additional use of equipment
- Loss of weed control chemical
- Loss of soil moisture
- Late planting
- Late harvest
- Additional insect control
- Increased boll rots

NOT Replanting

- Plants not uniform
- Skippy stand
- Loss of fertilizer
- Additional costs of weed control
- Weak plants more susceptible to other diseases and insects
- Oil and flaming more difficult
- Effect on mechanical harvesting

FIGURE 1.—Many factors are involved where cotton seedling diseases are a problem.

TABLE 3.—Means for number of cotton seedlings per acre (stand) and yield of seed cotton per acre with various soil fungicides at a rate of three pounds per bushel of seed using the hopper-box method of application, for year indicated, Northeast Louisiana Agricultural Experiment Station, St. Joseph

Fungicide	Per cent active ingredient	1962		1963		1964	
		Stand	Yield	Stand	Yield	Stand	Yield
PCNB + captan	10-10	58,500	984*	35,500	766*	30,250	1,424
PCNB + OM-2424	10-10			46,750	768*		
PCNB + maneb	10-10	58,450	932*				
Nabac + captan	3-7					27,750	1,462
Nontreated check		45,500	982*	39,750	742*	28,000	1,576
Replanted nontreated check			737	34,500	427	29,500	1,402
LSD at .05 level		NS	24	NS	66	NS	NS

*Significant at .05 level.

II. Symptoms and Causal Agents of Cotton Seedling Diseases

"Cotton seedling diseases" is a term for a relatively complex situation that involves an interaction between various disease-causing organisms and the environment. Very few disease complexes have been studied (*46*). Pathogens, or disease-causing organisms, are carried in one form or another either on the seed or inside the seed (*15, 21, 53*), or they live over from season to season in soil (*2, 12, 21, 27*). The presence of pathogens associated with seed or soil often cannot readily be detected in the field until infected cottonseed, seedlings, or larger plants show symptoms of infection. The cotton seedling disease complex includes the diseases called seed rot, seedling root rot, and pre- and post-emergence damping-off (Fig. 2).

A. Seed Rot

A number of pathogens either in soil or associated with seed cause deterioration of cottonseed after planting (*1, 2, 10, 12, 19, 20, 21, 24, 30, 46, 47*). Maier and Staffeldt (*21*) isolated nine different fungi and a bacterium from nonsterilized, acid-delinted seed. Presumably these organisms were carried inside the seed, since acid delinting destroys organisms on the outside of seed. Soil-borne organisms that attack and destroy cottonseed develop rapidly when nontreated seed are planted in cool, wet soil. After a pathogen rots one seed, it moves to other seed and either completely or partially rots them. As a result both seedling stand and vigor are reduced. *Rhizoctonia solani, Fusarium* sp., and other soil saprophytes are involved (*21*).

Pathogenic organisms borne on nontreated seed also cause diseases of cotton seedlings or mature plants later in the growing season (*1, 4, 8, 15, 19, 53*). These are the organisms that cause Ascochyta blight (*Ascochyta gossypii* Syd.) (*19*); bacterial blight (*Xanthomonas malvacearum* (E. F. Sm.) Dowson) (*8, 15*); anthracnose (*Colletotrichum malvacearum* Southworth) (*1, 4*); and Fusarium wilt (*Fusarium oxysporum* f. *vasinfectum* (Atk.) Snyder and Hansen) (*53*). Control of cottonseed rot is discussed under seed treatment.

Seed deterioration can result from improper handling of seed cotton during harvest, from storing cottonseed under unfavorable conditions (*6, 7, 16, 17*), or from chemical changes in the seed (*6, 7, 16, 17*). Such seed have low viability and are more susceptible to seed-rotting organisms (*6, 7, 16, 17*). A discussion of this topic is presented in the section dealing with seed quality.

B. Pre-emergence Damping-off

Pre-emergence damping-off is used to describe a disease of cotton seedlings that appears between seed germination and emergence.

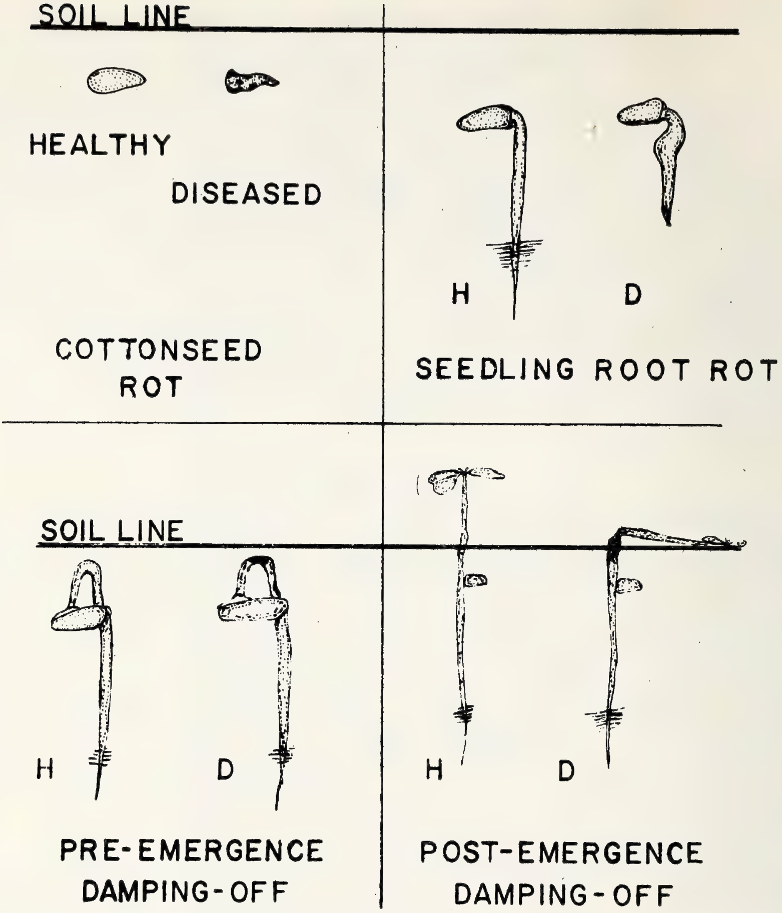

FIGURE 2.—Diagrammatic representation of four major phases of cotton seedling disease complex: seed rot; seedling root rot; pre- and post-emergence damping-off.

Symptoms are found on the newly formed root and are associated with root rot. The hypocotyl or stem also may be infected. Usually this latter type of infection is characterized by lesion formation at the crook of the hypocotyl, i.e., the first portion of the stem to emerge from the seed (Fig. 2). As the lesion continues to enlarge the stem is girdled. In either case, seedlings are killed or so weakened by infection that they cannot emerge. This results in reduced and uneven stands.

Both seed- and soil-borne pathogens cause pre-emergence damping-off. The soil-borne fungi *R. solani,* species of *Pythium, Fusarium,* and *Thielaviopsis* are the chief causal agents of this type of disease (*2, 5, 10, 12, 21, 24, 27*).

Control of pre-emergence damping-off is obtained through the use of seed and soil treatment. Both control measures are discussed in detail later.

C. Seedling Root Rot

Seedling roots might become infected any time after seed germination, but conspicuous symptoms and severe damage may not occur until after emergence of the seedling.

Several pathogens can cause cotton root rots, including species of *Fusarium, Pythium, Rhizoctonia,* and *Thielaviopsis* and other seed- and soil-borne organisms (*2, 5, 10, 12, 21, 24, 27*).

Symptoms of Fusarium root rot are a dry, dark-colored rot that progresses up the root and into the stem. These symptoms can be confused with post-emergence damping-off caused by *Rhizoctonia* sp. Pythium root rot is characterized by a light-colored, soft decay of the tap root and is most severe under very cool, wet conditions. *Rhizoctonia* sp. produces a dry, dark-colored rot over a wide range of conditions and is more important as a post-emergence damping-off organism. *Thielaviopsis* sp. causes a cortical rot which is brown to black. This fungus first rots tips of small feeder roots and then proceeds into the cortex of tap roots. The cortex of a diseased plant can be pulled away leaving the whitish stele. Only after isolation of the causal organism from diseased tissue can the pathogen involved be positively determined.

Environmental conditions, such as soil moisture and temperature and nutrients, have an important influence on incidence and severity of root rot infections. Seed and soil treatment, discussed in detail later, are means of controlling this phase of the seedling disease complex.

D. Post-emergence Damping-off

Symptoms of this disease appear at any time during the first part of the growing season (Fig. 2). A number of pathogens have been associated with this disease, including species of *Rhizoctonia, Fusarium, Pythium, Colletotrichum, Rhizopus, Aspergillus,* and *Penicillium,* and others (*2, 5, 10, 12, 21, 24, 27*). Isolations from diseased cotton seedlings collected from Louisiana fields showed that there were at least five fungi consistently involved (Table 4). Of these, *Rhizoctonia* sp. accounted for over half to three quarters of the infections.

R. solani incites the post-emergence damping-off disease of cotton called soreshin. Because this fungus is the most important one involved in seedling disease, many studies have been made on it by members of the L.S.U. Agricultural Experiment Station staff and will be reported here.

Plants infected with *Rhizoctonia* sp. under field conditions at first appear stunted and lighter green than normal. As the disease progresses, flagging (wilting at midday) becomes evident and lesions appear at or

TABLE 4.—The per cent occurrence of fungi isolated from diseased cotton seedlings collected at various locations in Louisiana for the year indicated

Fungus	Year 1962	 1963	 1964
Rhizoctonia sp.	51.5	66.4	28.2
Colletotrichum sp.	9.6	11.7	0.0
Fusarium sp.	8.0	5.8	30.6
Aspergillus sp.	5.3	5.8	0.0
Pythium sp.	1.1	2.2	15.3
Other (*Rhizopus* sp., *Diplodia* sp., and *Helminthosporium* sp., etc.)	24.5	8.1	25.9
Total	100.0	100.0	100.0

near the soil line on the hypocotyl or stem of the young plant. These lesions are at first light brown, changing to dark brown, then to black. As the fungus develops in the stem tissue, the infected area becomes collapsed and gives rise to a "wire-stem" appearance (Fig. 2). Under continued favorable conditions for disease development, infected plants topple over and die. Stands become uneven in height, skippy, and unthrifty.

Calcium deficiency may cause a collapse of the hypocotyl, yellowing and necrosis of cotyledonary leaves, and killing of the terminal growing point (*58*). These symptoms may be confused with those produced by fungus infection. If the plant survives, lateral roots are produced above the lesion and the plant does not have a tap root. This leads to the condition called "nub-root" in older cotton (*57*).

Penetration and infection of cotton stems by *Rhizoctonia* sp. takes place just before or after emergence. Symptom expression may be delayed depending on environmental conditions. Cool temperatures and abundant moisture are the two most important factors in disease development (*12, 13, 21, 30, 40, 41, 56*). Weather conditions favoring the growth of cotton, but not that of the fungus, can delay symptoms after infection; thus cotton seedlings infected in mid-April may not show severe symptoms until late May (*25*). Such cotton plants may continue to develop and outgrow the disease. Plants of this type, however, give rise to an uneven, unthrifty stand and may be damaged to such extent that, if infected plants survive, they are slowed down in their growth and become dwarfed when compared with noninfected plants. Such seedlings are more affected by thrips infestation (*26*) and other adverse conditions (*24, 35, 37, 38*). Cotton in a field with this condition can be severely damaged or killed when oil or flaming techniques are applied for weed control. These dwarfed plants, also, are more susceptible to damage by certain lay-by herbicides than are noninfected plants.

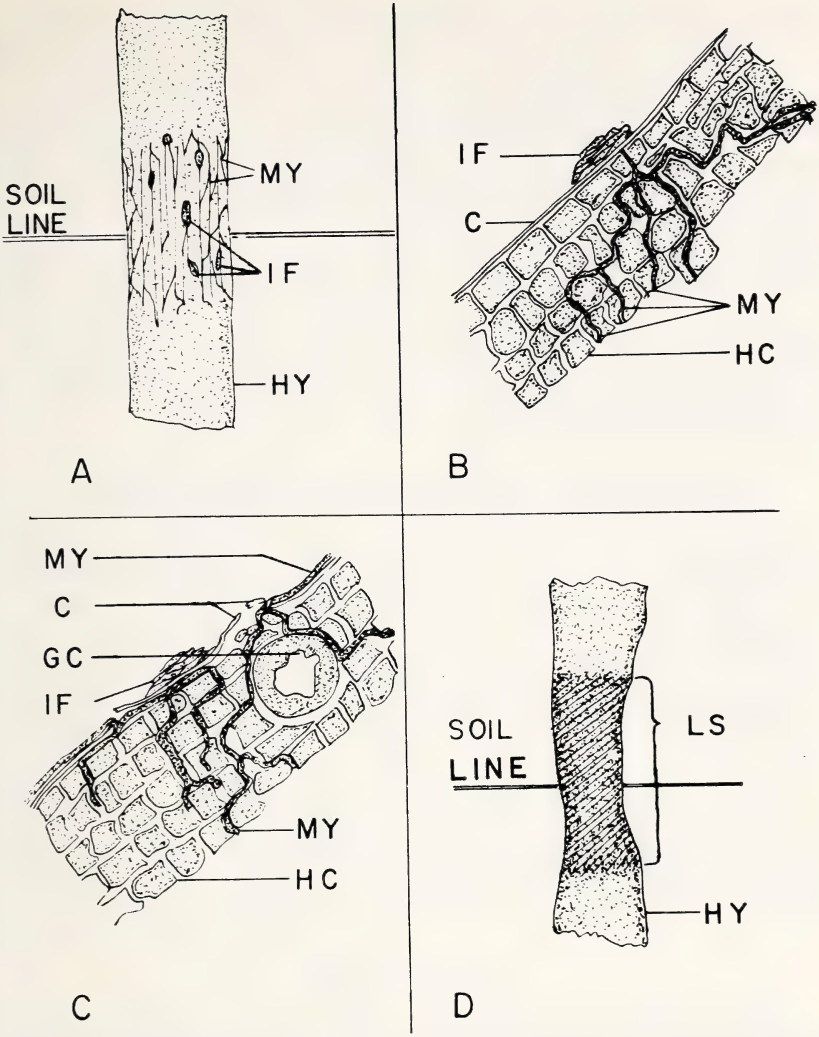

FIGURE 3.—Diagrammatic representation of penetration of and infection by Rhizoctonia solani Kuhn on cotton seedling hypocotyl. A) The fungus mycelium (MY) oriented itself longitudinally on hypocotyl (HY) and formed infection cushions (IF). B) Penetration of the host tissue by mycelium (MY) took place under the infection cushion (IF), through the cuticle (C); mycelium then grew between and through host cells (HC). C) The fungus mycelium (MY) penetrated without infection cushions (IF) where the epidermis and cuticle (C) of the hypocotyl had been opened by the enlargement of gland cells (GC) or injury. D) After initial penetration, the fungus grew into adjacent tissue both above and below the soil line and caused a conspicuous lesion (LS) on the hypocotyl (HY).

To better understand the infection process and development of the *Rhizoctonia* sp. fungus in the stems of seedling cotton, a study was made by Khadga, Sinclair, and Exner (*18, 52*). Using standard techniques, they made a microscopic examination of cotton seedling hypocotyls infected with *R. solani*. It was found that the fungus was able to penetrate mechanically the cuticle, epidermis, and first layers of cortical tissue. Penetration occurred beneath a specialized structure called an infection cushion (Fig. 3A). The infection cushion was formed by the intermingling of hyphae of the fungus. After penetration the fungus was able to grow between and through the cells of various plant tissues (Fig. 3B). It was found that within 48 hours after penetration, tissues about centers of invasion were completely disintegrated (Fig. 3C). After infection was established, the fungus continued to grow into adjacent plant tissue (Fig. 3D).

III. Control of Cotton Seedling Diseases

Control of cotton seedling diseases comes through the use of preventative measures rather than cure. Some plant diseases are controlled by the development of varieties resistant to the pathogen. At present the breeding for resistance to seedling diseases seems remote because of the variety of organisms involved in the complex (*2, 12, 21*), the variation in susceptibility to various isolates of *Rhizoctonia* sp. (*10, 21, 43, 44, 51*), and the lack of a high type of resistance to all races of *Rhizoctonia* sp. (*44*).

Cottonseed and seedlings must be protected from infection. There are three main control measures that should be practiced to reduce losses from cotton seedling diseases. These are: the use of high quality cottonseed, seed treatment, and soil treatment. Each of these will be discussed separately and in detail.

A. Seed Quality

"High quality seed" refers to cottonseed that are genetically pure and free of inert matter, weed seed, damage, and seed-borne disease organisms. The term is used also to define the ability of cottonseed to give a stand of vigorous, healthy cotton seedlings even under adverse conditions for germination and emergence (*6, 7*). High quality seed are more tolerant to low temperatures and less susceptible to attacks by soil-borne pathogenic organisms (*7*). Annotated bibliographies on seed storage and deterioration have been published (*16, 17*).

Poor quality seed have reduced germination rates and result in spotty, uneven stands, with weak seedlings and plants that are more susceptible to disease, insect damage, and adverse weather conditions (see Section IV). Deterioration of the embryo root within cottonseed also is the principal cause of nubroot (*57*). Poor quality cottonseed can be the result of deterioration either in the field or in storage where improper temperatures and humidity levels cause deleterious chemical changes in the seed.

Primary factors affecting cottonseed deterioration in the field are high moisture and delayed harvest. Defoliation is desirable when cotton is rank or boll rot is excessive. Several practices will preserve cottonseed quality between harvest and ginning. Only dry seed cotton should be harvested, but if wet cotton is harvested, it should be ginned immediately. Damp seed cotton should not be force-packed in trailers. Wire mesh or open-walled trailers provide air circulation required to reduce cottonseed deterioration in damp or wet cotton.

The primary factors affecting cottonseed deterioration in storage are: temperature and humidity within the seed, length of storage, infestation with microorganisms, and air permeability of bulk seed. Other factors are: external humidity and temperature and the extent of preharvest seed deterioration (*6, 7*). Cottonseed should be stored in dry conditions to maintain a 10 per cent moisture content of the seed.

Partially deteriorated cottonseed may germinate well during standard germination tests in the laboratory but result in a poor stand in the field. Per cent germination tests should be run as close to planting time as is feasible.

Germination tests often are not sufficient to determine the extent to which cottonseed have deteriorated or the stand that can be expected from the seed. Dual temperature germination tests and/or tests measuring the resistance to the passage of electric current through water containing cottonseed can be used to determine more precisely the extent of seed deterioration and infection by pathogenic organisms (*6, 7*).

Only the highest quality seed available should be planted. If high quality seed is not available, it has been reported in Mississippi that calcium as a seed treatment was beneficial to weak seedlings developed from partially deteriorated seed (*58*).

B. Seed Treatment

Seed treatment involves various techniques and/or chemicals for controlling disease-causing organisms that attack propagative stocks, seed, and seedlings. Seed treatment is the most important and most economical method of controlling certain seedling diseases. For some seed- and soil-borne diseases, seed treatment is the only means of control (*48, 49, 50*).

One of the most critical periods of plant growth and development is from seed germination to independent establishment of the seedling. It is during this period that young cotton plants are most susceptible to disease-causing organisms that incite seed rot, damping-off, stem blight, and root rot. Treatment of cottonseed controls not only these disease-causing organisms but also other organisms whose symptoms may not appear until the plant is near maturation. The anthracnose and bacterial blight pathogens are good examples of this latter type.

A wide range of organisms cause diseases of cottonseed and seedlings, including bacteria, fungi, nematodes (*38*), and insects (*26*). Bacteria and fungi are found either on the outside or inside of cottonseed. A seed is said to be *infested* when disease organisms are carried on the outside of seed. If the seed has pathogens established under the seed coat or in seed tissues, it is *infected*. It follows that a method or material found to kill or mitigate the pathogen on the outside of the seed would be called a *disinfestant* and would be used to disinfest the seed. On the other hand, a *disinfectant* would be used to disinfect the seed. Cottonseed may be free of disease-causing organisms but still be subject to attack by pathogens in the soil. Seed treatment materials used to protect seed from these pathogens are called *protectants,* or protective materials.

To control disease-causing organisms infecting seed without killing the seed is a delicate problem. Two methods have proved effective. One uses hot water and the other requires the use of volatile fungicides, such as formaldehyde. Seed treated by either of these methods, however, are not protected from soil-borne pathogens and must be treated, in addition, with a protectant-type seed treatment before planting.

Practically all effective cottonseed treatment materials are disinfectants and many, in addition, have protective qualities. These materials may come in the form of a dust, powder, or liquid. These types of seed treatment materials are most familiar and are widely used for cottonseed treatment.

Seed treatment is not a substitute for high quality seed. Generally, poor quality cottonseed receive more benefits from seed treatment than good quality seed, in that, poor quality seed that might not survive are given a chance to grow.

Seed treatment cannot improve environmental conditions. Unless soil temperatures and moisture are good for germination, no amount of seed treatment material will help.

The Louisiana Agricultural Experiment Station cooperates with the Cotton Disease Council in the regional cottonseed treatment tests. Each year a large number of new seed treatment chemicals are compared with certain standards and with nontreated seed. The tests are planted in randomized, replicated blocks with 25 hills for each seed treatment. Each hill is planted with five seed. Stand counts and field data are collected and analyzed (Table 5). From these tests cottonseed treatment materials and rates for Louisiana are suggested (Table 6).

C. Soil Treatment

High quality seed and seed treatment help produce an even, desirable stand of cotton at the first planting. However, these practices are

TABLE 5.—Means for number of cotton seedlings per acre (stand) and yield of seed cotton per acre from regional seed treatment tests on reginned cottonseed, for treatment, rate in ounces per 100 pounds of seed, and year indicated at Northeast Louisiana Agricultural Experiment Station, St. Joseph. (A portion of the data for each year of four years is reported.)

		1961		1962		1963		1964	
Treatment	Rate	Stand	Yield	Stand	Yield	Stand	Yield	Stand	Yield
Nontreated	....	43	2,620	18	1,498	43	3,254	55	1,647
Captan 75	1.5	36	1,741						
	3.0	43	2,521						
Ortho LM	3.0	48	3,265*						
Ceresan L	2.0	60	2,902*						
	3.0	46	3,047*	29*	2,387	63	3,450	62	1,647
Ceresan M	3.0	46	2,920*	38*	2,422	58	3,620*	67*	1,634
Chipcote 25	1.0			37*	2,631				
	1.5			30*	2,701				
Chipcote 75	2.0			18	2,526				
	3.0			25*	2,178				
Dexon	3.0			25*	2,091	46	2,927		
Elcide 70	2.0	50	3,319*	19	1,934				
	3.0			22*	1,777				
Gallatox	3.0							52	2,208
Isobac 20	8.0					41	2,914	55	1,816
3M-AR990A	1.0			22*	2,352	46	3,502*		
	2.0			22*	2,091	40	3,385		
Panogen 15	2.0	50	3,011*						
	3.0	52	2,939*	25*	2,126	62	3,332	65*	1,803
PCNB + captan	4+3	50	2,630	34*	2,544				
PCNB + Ceresan M	4+3	58	3,174*	38*	2,526			77*	1,464
PCNB+ Dexon	4+3	50	3,011*	38*	2,718				
PCNB + Panogen 15	4+3	52	2,830*	34*	2,317	63	4,090*	63	2,104
PCNB + OM-2424	4+3							81*	1,647
LSD at .05 level		NS	60	4	NS	NS	234	10	NS

*Significant at .05 level.

TABLE 6.—Suggested cottonseed treatment guide for Louisiana

Fungicide	Manufacturer or company	Ounces per 100 pounds	
		Machine-delinted	Acid-delinted
Agrox	Chipman Co.	4.0	3.0
Captan 75	Stauffer Chem. Co.	3.0	2.0
Orthocide LM	Calif. Chem. Co.	3.0	2.0
Ceresan L	DuPont	3.0	2.0
Ceresan M	DuPont	3.0	2.0
Chipcote 25	Chipman Chem. Co.	2.0	2.0
Chipcote 75	Chipman Chem. Co.	3.0	3.0
Elcide 70	Eli Lilly	3.0	2.0
Panogen 15	Morton Co.	3.0	2.0
PCNB 75 + Captan 75	Several companies	4.0+3.0	4.0+2.0
PCNB 75 + Ceresan L	Several companies	4.0+3.0	4.0+2.0
PCNB 75 + Panogen 15	Several companies	4.0+3.0	4.0+3.0

not enough to hold a uniform stand in areas where soil-borne pathogens and environmental conditions are favorable for disease development. To maintain a uniform stand of cotton, soil-borne pathogens must be controlled. Control of pre- and post-emergence damping-off and root rot is accomplished by fungicidal treatment of soil that surrounds seed (*4, 5, 21, 28, 29, 32, 34, 35, 36, 41, 45, 46, 47, 57*). There are four ways in which soil fungicides can be incorporated into the soil at the time of planting (Fig. 4). These are: hopper-box method, in-the-furrow spray, in-the-furrow dust, and use of granular applicators. Each method will be discussed separately. The acreage treated with soil fungicides in Louisiana ranged from 13 to 18 per cent between 1961 and 1964 (Table 2).

Hopper-box Method

Application of soil fungicides by the hopper-box method has been studied for several years in Louisiana (*28, 29, 47, 49*). This method

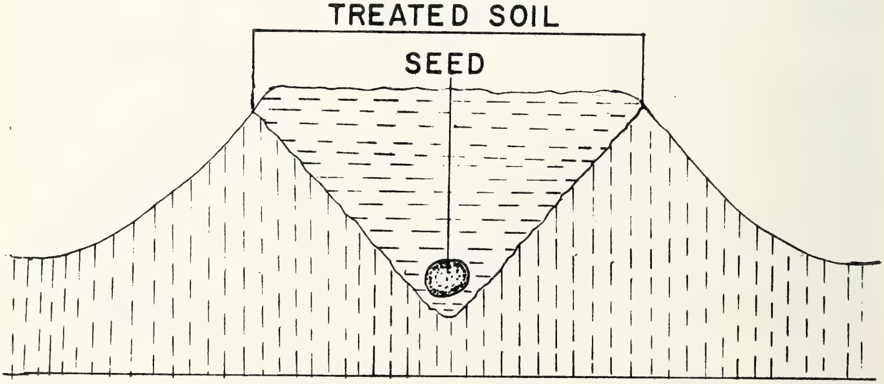

FIGURE 4.—Ideal placement of a soil fungicide around cottonseed at the time of planting for controlling cotton seedling diseases.

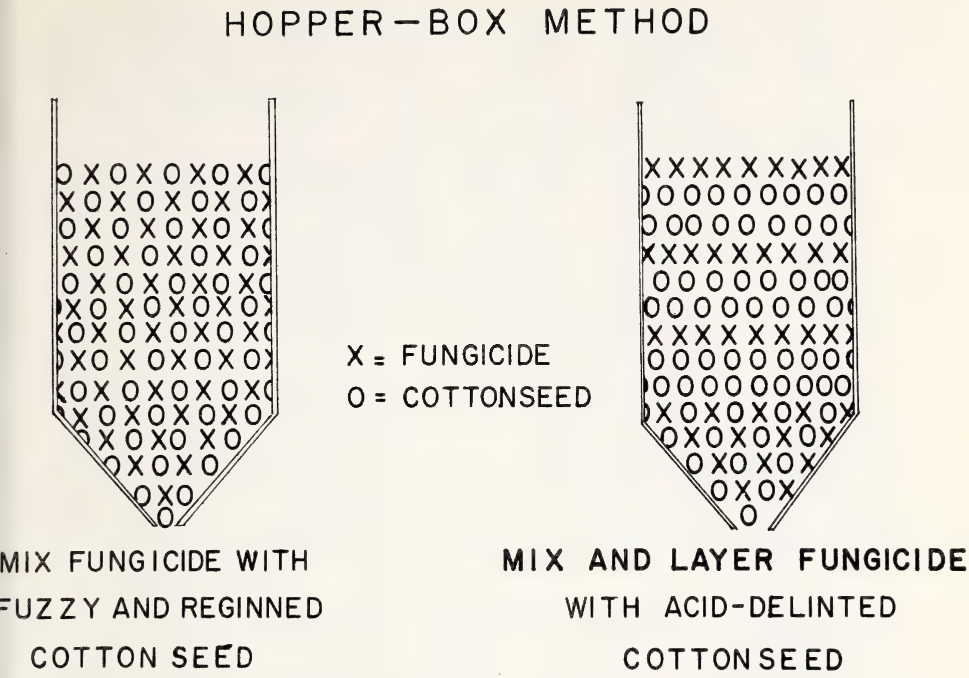
HOPPER-BOX METHOD
X = FUNGICIDE
O = COTTONSEED
MIX FUNGICIDE WITH FUZZY AND REGINNED COTTON SEED
MIX AND LAYER FUNGICIDE WITH ACID-DELINTED COTTONSEED

FIGURE 5.—A hopper-box method of applying soil fungicides at the time of planting for controlling cotton seedling diseases. The manner in which the fungicide is mixed with cottonseed depends on whether or not acid-delinted seed are used.

requires that fungicides be mixed with cottonseed either before the seed are placed in the hopper-box or during the planting operation, depending on whether acid-delinted or reginned seed are used (Fig. 5). When reginned seed are used, fungicide and seed should be thoroughly mixed in a separate container. This mixture then is placed in the hopper-box for planting.

Although not recommended for acid-delinted seed, this method can be used for such seed but special handling is then required. Fungicides do not adhere readily to the smooth surface of acid-delinted seed, and consequently they tend to accumulate, during the planting operation, at the bottom of the seed hopper. This disadvantage can be overcome either by adding fungicide to the seed as needed during the planting operation or by placing a layer of seed mixed with fungicide in the bottom of the seed hopper, then a layer of seed without fungicide, followed by a layer of fungicide. This layering is repeated once or twice, depending on the height of the hopper box (Fig. 5).

A large number of fungicides, alone or in combination, have been evaluated for their effectiveness in controlling cotton seedling diseases

TABLE 7.—Means for number of cotton seedlings per acre (stand) and yield of seed cotton per acre with various soil fungicides at a rate of three pounds per bushel of seed, using the hopper-box method of application, for year and location indicated. (These data represent portions of larger experiments.)

	Per cent	1961			1962				1963				1964			
	active	Curtis	St. Joseph		Curtis		St. Joseph		Curtis		St. Joseph		Curtis		St. Joseph	
Fungicide	ingredient	Stand	Stand	Yield	Stand	Yield	Stand	Yield	Stand	Yield	Stand	Yield	Stand	Yield	Stand	Yield
Nontreated check		60,250	58,750	2,806	39,750	1,303	28,500	2,795	22,750	1,313	59,500	1,943	57,500	916	25,500	2,813
PCNB	15						36,250*	2,546	35,500*	1,372	56,000	1,998				
PCNB + captan	10-10	59,500	52,500	2,556	26,000	1,168	43,750*	2,860*	35,750*	1,310	65,750	1,958	54,750	811	28,750	2,705
PCNB + OM-2424	10-10				29,000	1,331	51,750*	2,948	37,750*	1,347	62,750	2,118	61,250	720	30,500	2,750
PCNB + maneb	10-10	66,500*			39,750	1,313	41,000*	2,628								
PCNB + M45	10-10												60,250	739	29,500	2,745
PCNB + thiram S-42	10-10				32,250	1,336	41,750*	2,824*	32,250*	1,262	57,500	1,805	57,750	909	26,750	2,735
OM-2424	10								33,500*	1,305	68,000	2,218	61,250	706	31,000	2,775
Nabac + captan	3-7	41,750			40,000	1,491*	61,000*	3,180*	30,250*	1,413	66,000	1,873	49,250	712	28,000	2,680
Dexon + 2635	2.5-10				23,750	926			29,500*	1,190			59,250	981	31,750	2,590
LSD at .05 level		3,750	NS	NS	750	118	1,250	11	6,750	NS	NS	NS	6,900	NS	NS	45

*Significant at .05 level.

when applied by the hopper-box method (*28, 29, 47, 49*). Selected data from 4-year results are presented in Table 7. Suggestions for materials to be used in Louisiana are based on these and other results (Tables 7, 8, 12, 13, 14, 15, 16, 17).

In 1962, 1963, and 1964, regional soil treatment tests were conducted in cooperation with the Cotton Disease Council. The same fungicides, seed source, and method of application were used in all tests. The results of these tests are presented in Table 8.

Results indicated that a combination of fungicides must be used for best control. PCNB in combination with other fungicides such as captan, maneb, thiram, dexon, or OM-2424 is most effective. Other materials that show promise are OM-2424 used alone, or a combination of PCNB plus folpet.

For the hopper-box method, use the rate of fungicide suggested on the label. In general, soil fungicides are mixed with cottonseed at a rate of 1 pound of fungicide to 10 pounds of seed, with a minimum application of 3 pounds of fungicide per acre (Table 17). When fungicides are mixed with the seed, it is necessary to recalibrate the planter to the desired seeding rate because many fungicides tend to reduce the seeding rate (Table 9).

The hopper-box method is the easiest and quickest to use. The method, however, is the least efficient of the four methods, and gives only reasonably desirable distribution of fungicide and protection. It cannot be used where it is desirable to plant cottonseed more than an inch in depth. Fungicides tend to concentrate toward the bottom of the hopper-box because of agitation and settling of the fungicide during the planting operation. The first seed planted, therefore, will tend to have more fungicide than the last. Some planters do not adapt well to this method and become clogged.

In-the-Furrow Spray Method

This method is more effective than the hopper-box method and involves the use of an adapted low-pressure insecticide or herbicide sprayer operated by a pump from the power take-off (Fig. 6). Hoses lead from the pump to ¼-inch pipes about 10-15 inches long fitted with two spray nozzles per row. The first nozzle should be centered on the furrow so that the spray strikes the soil around the seed and 3 inches on each side of the seed furrow. Optimum height of the front nozzle is 1½—3 inches above the original soil surface. The rear nozzle should be directed to spray soil as it is tumbled into the seed furrow, with a small fraction of the spray to strike the top of the covered row. Nozzles to use and suggested pressures are given in Table 10. A method for accurately determining planting speed in miles per hour in order to select proper nozzle tips is given in Table 11.

From 1960 to 1964 a large number of soil fungicides were evaluated

TABLE 8.—Means for number of plants per acre (stand) and yield of seed cotton per acre with various soil fungicides at a rate of three pounds per bushel of seed, using the hopper-box method of application, for year and location indicated. (These data are part of the cooperative regional soil treatment tests.)

	Per cent	1962			1963				1964	
	active	Curtis	St. Joseph		Curtis		St. Joseph		St. Joseph	
Fungicide	ingredient	Stand	Stand	Yield	Stand	Yield	Stand	Yield	Stand	Yield
Nontreated check		32,750	29,750	2,795	22,750	1,313	59,500	1,943	25,500	2,813
PCNB	15	34,250	32,250*	2,546	35,500*	1,372	56,000	1,998		
PCNB + captan	10-10	50,250	43,750*	2,860*	35,750*	1,310	65,750	1,958	28,750	2,705
PCNB + maneb	10-10	40,250	41,000*	2,628						
PCNB + thiram	10-10	33,750	41,750*	2,824*	32,250*	1,262	57,500	1,805	26,750	2,735
PCNB + OM-2424	10-10				37,750*	1,347	62,750	2,118	30,500	2,750
Nabac + captan	3-7	40,000	51,000*	3,180	30,250*	1,413	66,000	1,873	28,000	2,680
OM-2424	10				33,500*	1,305	68,000	2,218	31,000	2,775
LSD at .05 level		NS	1,250	11	6,750	NS	NS	NS	NS	45

*Significant at .05 level.

TABLE 9.—Effect on seeding rate of mixing various fungicides with cottonseed, using the hopper-box method of application for two field experiments, 1964

Fungicide	Per cent active ingredient	Per cent seed planted in 800 row feet Experiment number 1	 2
PCNB + captan	10 + 10	25	33
PCNB + M-45	10 + 10	22	27
Nabac + captan	.75 + 7	22	27
PCNB + thiram S-22	10 + 10	22	27
PCNB + OM-2424	10 + 10	. .	24

for their effectiveness in controlling cotton seedling diseases by the in-the-furrow spray method (*28, 29, 47, 49*). Selected data from these tests are presented in Table 12. Suggestions for materials to be used in Louisiana are based on these and other results (Tables 12, 13, 14, 15, 16).

Results indicated that PCNB in combination with other fungicides gave best results. An increase in rate of fungicide over that used for the hopper-box method is required, because a greater amount of soil is treated. Read package labels for specific rates of material to be used. In general, a rate of 10 pounds of formulated material per acre is required (Table 17). Use only fungicide in emulsifiable concentrate or wettable powder form. Dusts used for the hopper-box and dust methods are not satisfactory.

In 1961, a series of tests were conducted to determine if soil fungicides might be effective in controlling cotton seedling diseases when applied to the soil surface alone or in combination with a herbicide, diuron. Results indicated that this method was of little value (Table 13).

The in-the-furrow spray method has proved to be more effective than the hopper-box method (Tables 14, 15). Advantages are that the fungicide distributes better in the soil, the method can be used where seed are planted below one inch, either acid-delinted or reginned seed can be used, and there is no clogging of the planter.

The disadvantages of this method are the necessity of having to stop and refill tanks with water plus fungicide during the planting operation, and competition for use of the power take-off if a grower wishes to apply a pre-emergence herbicide at the time of planting. The latter problem can be solved by using a special two-pump system on the power take-off to operate both spray systems.

In-the-Furrow Dust Method

This method involves the mixing of soil and fungicides by using a low air velocity duster (Fig. 7) that blows dust through special distribution tubes or shoes (Fig. 7F) located at a point or points between the furrow opening and closing apparatus (Fig. 7C, D, E). A suitable rig,

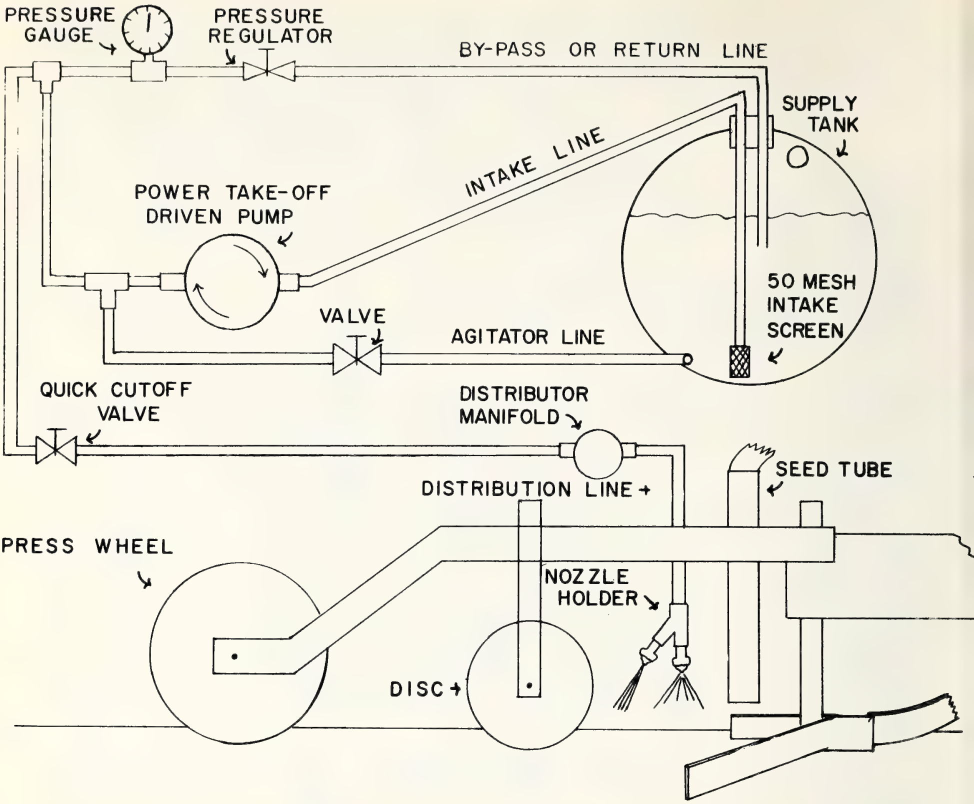

FIGURE 6.—Suggested apparatus for in-the-furrow spray application of soil fungicides at the time of planting for controlling cotton seedling diseases.

which can be attached to a planting rig or tractor, called a "Chem-Soil Mixer" (Gustafson Mfg. Co., Corpus Christi, Texas) can be used and is suggested. Special distribution tubes and shoes are available. This apparatus can be operated from the power take-off (Fig. 7B) or by an auxillary gas engine (Fig. 7A).

The mixing of soil and fungicide by this method was studied and found to give better results than either hopper-box or in-the-furrow spray methods (Tables 14, 15, 16). Dusts containing Terraclor (PCNB) plus other fungicides such as captan, maneb, thiram, and dichlone are suggested for use with this method.

Dusts are applied at a rate of 10-15 pounds per acre and should contain the suggested amounts of active fungicides for adequate treatment (Table 17). Follow instructions on the container recommended by the manufacturer.

In-the-furrow dust equipment has been used successfully in Texas

TABLE 10.—Suggested single or combination Tee Jet Nozzle tips (40 p.s.i.) (From Olin Mathieson Chemical Corporation Publication AD-1160-161.)

Planting Speed	10 gal./Acre	15 gal./Acre
	Two Nozzles per Row	
3.0 MPH	2–¼ TT X6	1–¼ TT X6 1–¼ TT 6502
3.5	1–¼ TT X6 1–¼ TT X6	1–¼ TT X8 1–¼ TT 6502
4.0	2–¼ TT X8	1–¼ TT X10 1–¼ TT 6503
4.5	1–¼ TT X8 1–¼ TT X10	1–¼ TT X10 1–¼ TT 6503
5.0	2–¼ TT X10	1–¼ TT X10 1–¼ TT X20
	(Use 50-mesh screens)	
	One Nozzle per Row	
3.0 MPH	¼ T X12	¼ T X18
3.5	¼ T X14	¼ T X20
4.0	¼ T X16	¼ T X24 or
4.5	¼ T X18	¼ T 6504
	12 gal./Acre ¼ T X26	
	(Use 50-mesh screens)	

TT = Male Connection.
T = Female Connection.

for a number of years. It is particularly adapted to lighter soils and large acreages. The initial cost for equipment is greater than that used for other methods. Seed can be planted below one inch. Since a greater amount of soil is treated than with the hopper-box method, a larger amount of fungicide is required per acre.

Use of Granular Applicator

Some recent work at other experiment stations has shown that fungicides in granular form might be applied by using any gravity-flow type of granular applicator similar to those used for the application of granular fertilizers and insecticides. The granules are metered through a distribution tube, which should be placed between the seed drop tube and covering discs. The results of these experiments indicate that more work has to be completed before suggestions can be made.

TABLE 11.—A method for accurately determining planting speed in miles per hour in order to select proper nozzle tips (From Olin Mathieson Chemical Corporation Publication AD-1160-161.)

1. After setting planter and starting tractor on a straight course, use proper gear and throttle to attain normal planting speed.
2. After normal planting speed is attained, drop one object off the tractor to mark a starting point. Exactly 30 seconds later, drop a second object off the tractor. (If two people are available, the second person can time and mark the starting and stopping point.)
3. Measure the distance between the two objects in feet.
4. Obtain tractor speed from the following table:

Distance travelled in 30 Seconds	Tractor Speed
132 feet	3.0 MPH
143	3.25
154	3.5
165	3.75
176	4.0
187	4.25
198	4.5
209	4.75
220	5.0

Individual growers may wish to try the application of granular fungicides on a limited basis until Experiment Station recommendations are available. Instructions provided by the manufacturer or county agents should be followed.

Advantages in using granular application of fungicide are: easy handling; the applicator can work off the drives on a planter; and the equipment is relatively less expensive than that needed for in-the-furrow sprays and dusts.

Materials to Use

The use of soil fungicides in Louisiana has been limited (Table 2). About 15 per cent of affected acres have been treated with soil fungicides from year to year. There are a number of labeled products on the market. In greenhouse and field tests (Tables 3, 7, 8, 12, 13, 14, 15, 16) over the past eight years a number of materials, alone or in combination, have proved effective in controlling post-emergence seedling damage caused by soil-borne organisms. When compared to other materials, PCNB alone or in combination with either captan, maneb, thiram, dichlone, dexon, or OM-2424 has given good results (Tables 3, 7, 8, 12, 13, 14, 15, 16). PCNB plus OM-2424 has shown the most promise.

The fungicides suggested for soil treatment are available under a number of trade names and labels. Container labels should be read carefully noting fungicides included and their per cent active ingredient. PCNB is known commercially as Terraclor; captan as either Captan or Orthrocide; maneb as either Manzate or Dithane; dichlone as Phygon; thiram as Thylate; and folpet as Phaltan.

TABLE 12.—Means for number of plants per acre (stand) and yield of seed cotton per acre with various soil fungicides at rates of five pounds per acre for powders and one to four quarts per acre for liquids applied as in-the-furrow sprays for year indicated. (These data represent portions of larger experiments.)

Fungicide	Per cent active ingredient	1960	1961	1962				1963				1964			
		Curtis	Curtis	Curtis		St. Joseph		Curtis		St. Joseph		Curtis		St. Joseph	
		Stand	Stand	Stand	Yield	Stand	Yield	Stand	Yield	Stand	Yield	Stand	Yield	Stand	Yield
Check		83,800	57,250	33,750	1,609	37,250	3,202	25,750	1,060	59,500	1,943	57,500	916	25,500	2,813
PCNB-EC			79,000*	31,500	1,664							64,500*	1,125		
PCNB + captan	10-10	153,750*	57,250	44,250	1,853*										
PCNB + dichlone	10-10	147,500*													
PCNB + dexon	35-35	141,750*	55,500												
PCNB + OM-2424	10-10			40,750	1,671	40,750*	2,962	42,750*	1,155*	78,750*	2,080	67,000*	1,092	35,000*	2,698
PCNB + maneb	10-10			36,500	1,687*										
PCNB + thiram	10-10			40,000	1,723*										
PCNB +126B				38,500	1,586									26,500	2,798
Thiram	50	114,500*						39,000*	1,246*						
OM-2424 EC								38,750*	1,262*						
Nabac	25							33,750*	1,246*						
LSD at .05 level		10,000	4,250	NS	78	2,500	NS	5,250	60	11,250	NS	2,929	NS	4,600	NS

*Significant at .05 level.

TABLE 13.—Means for number of plants in 52 feet of row from soil whose surface was sprayed with various soil fungicides either in combination with diuron or without at rates of either four quarts per acre for liquids or five pounds per acre for powders at location indicated

	Fungicide, location and use of diuron				
	Baton Rouge			St. Joseph	
Fungicide 4 qts./A.	With diuron	Without diuron	Fungicide 5 lbs./A.	With diuron	Without diuron
Nontreated check	127	153	Nontreated check	174	150
PCNB EC	136	149	PCNB + captan 10-10	183	196*
Thiram EC	152	157	PCNB + folpet 10-10	187	166*
Dow Zectran	158	152	PCNB + maneb 10-10	185	183*
Tin-San	163	149	PCNB + thiram 10-10	186	201*
Quick-San	149	148	Nabac 25	187	153*
5961	150	159	Nabac + captan 10-10	173	182*
LSD$_{05}$	NS	NS	LSD$_{05}$	NS	13

*Significant at .05 level.

A grower may wish to try one or more of these materials on a small part of his land for experimental purposes. It should be remembered that materials that work well as a liquid or dust may not give the same response when used in the hopper-box. Suggested materials to use and rate based on the method of application are given in Table 17.

Cost of Materials

The spray and dust methods give better control than the hopper-box method but require additional equipment and more fungicide per acre because more soil is treated when they are used. Spray and dust methods of applying soil fungicides, therefore, are a little more costly than the hopper-box method. Stand increases of about 20 to 25 per cent are obtained at a cost of about $3.50 to $5.00 per acre depending on method and material used. These costs for all three methods are based on a mixture of two soil fungicides.

The use and application of soil fungicides must be thought out in view of costs and results. Working with the county agent, the grower should decide if he has a seedling disease problem and if so, how he can best control it. The control method must be worked into the grower's present program of fertilizer application, weed control, and nematode control. Later planting, rather than the use of soil fungicides, may give seedling disease control and should be considered.

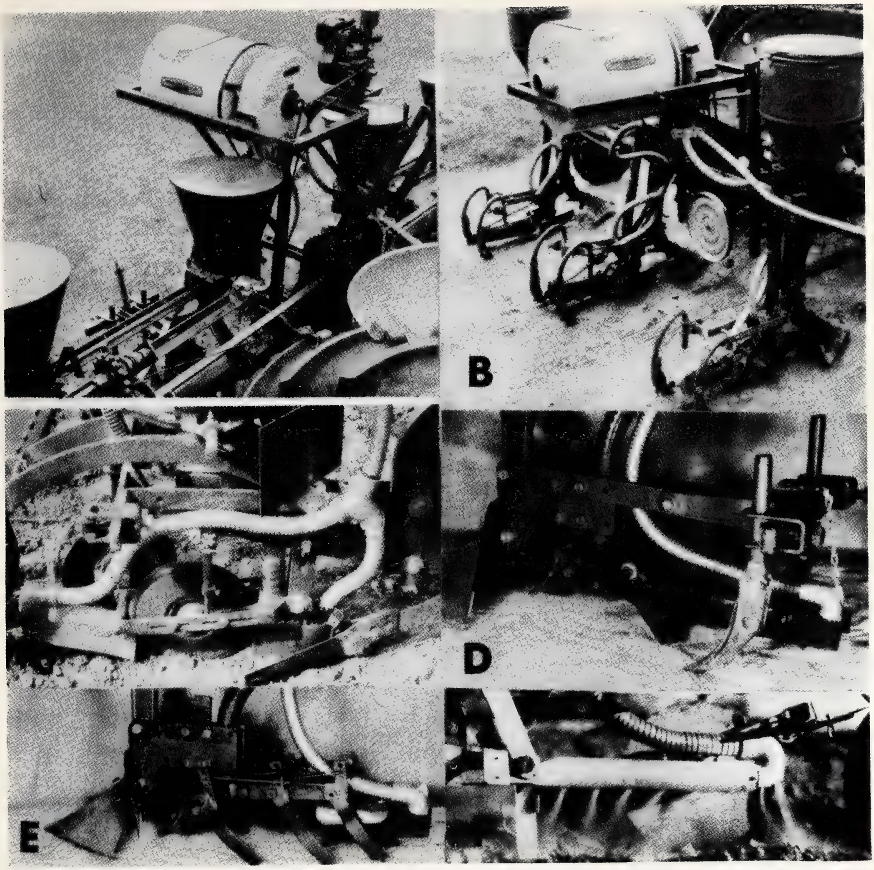

FIGURE 7.—Equipment for in-the-furrow dust application of soil fungicides. A. Side view showing engine-powered arrangement. B. Side view showing attachment to power take-off. C. Showing attachments for use with seed embedding wheels. D. and E. Showing attachments for other covering devices. F. Dust pattern from special attachment. (From Olin Mathieson Chemical Corporation Publication AD-1160-161.)

IV. Effect of Environment and Other Factors on Cotton Seedling Diseases

Environmental conditions determine the extent of soreshin development in any one area. Conditions favorable for the disease may occur one year but not the next. Any condition that is unfavorable for development of the cotton seedling and favorable to the pathogen makes cotton more susceptible to seedling diseases (*19*). Some growers have a long

TABLE 14.—Means for number of plants per acre with various soil fungicides applied by three methods. (A portion of a larger experiment is given.)

Fungicide	Per cent active ingredient	Method and rate: In-the-furrow spray, 4 qts./A.			
		In-the-furrow spray, 4 qts./A.	Hopper-box, 3 lbs./bu.		In-the-furrow dust, 5 lbs./A.
		Curtis	Curtis	St. Joseph	St. Joseph
Nontreated check		57,250	60,250	58,750	58,750
PCNB + captan	10-10	57,250	59,500	56,250	52,500
PCNB + maneb	10-10		66,500*		
Nabac	25	39,000		45,500	
Nabac + captan	10-10		41,750		64,750
PCNB + folpet	10-10	56,750			
2635	70		12,750		66,250
3944	2		55,250		63,750
PCNB + dexon	35-35	55,500			
PCNB + dichlone	10-10	61,750			
LSD at .05 level		4,250	3,750	NS	NS

*Significant at .05 level.

TABLE 15.—Means for number of plants per acre with various soil fungicides applied by three methods. (A portion of a larger experiment is given.)

Fungicide	Per cent active ingredient	Method and rate of application		
		Hopper-box, 3 lbs./bu.	Dust, 10 lbs./A.	Spray, 10 lbs./A.
Nontreated check		84,000	84,000	84,000
PCNB + captan	10-10	111,750	133,000*	153,750*
PCNB + dichlone	10-10	37,750	134,500*	147,500*
PCNB + thiram	10-10		154,500*	
PCNB + dexon	35-35	115,000	71,000	141,750*
LSD at .05 level		35,500	11,250	10,000

*Significant at .05 level.

TABLE 16.—Means for number of plants per acre with various soil fungicides applied by three methods at Red River Valley Agricultural Experiment Station, Curtis

Fungicide	Per cent active ingredient	Method, rate, and experiment number					
		Hopper-box, 3 lbs./bu.		Spray, 10 lbs./A.		Dust, 10 lbs./A.	
		1	2	1	2	1	2
Nontreated check		84,000	28,500	84,000	57,250	84,000	21,750
PCNB + captan	10-10	121,750	44,500*	153,750*	57,250	133,000*	34,750
PCNB + dexon	35-35	115,000	21,250	141,750*		71,000	59,000
PCNB + dichlone	10-10	37,750	58,250*	147,500*	61,750*	134,500*	43,250
PCNB	EC				79,000*		
LSD at .05 level		NS	4,250	10,000	4,250	11,250	NS

*Significant at .05 level.

TABLE 17.—Suggested* fungicides and rates in pounds per acre for use as a soil treatment to control cotton seedling diseases, based on method of application to be used

Fungicide	Per cent active ingredient	Minimum and maximum rates in pounds or pints per acre for use with:		
		Hopper box	Spray method	Dust method
PCNB + captan	10-10	3 – 5 lbs.	5 – 10 lbs.	10 – 15 lbs.
PCNB + thiram	10-10	3 – 5 lbs.	5 – 10 lbs.	10 – 15 lbs.
PCNB + maneb	10-10	3 – 5 lbs.	5 – 10 lbs.	10 – 15 lbs.
PCNB + OM-2424	10-10	3 – 5 lbs.	5 – 10 lbs.	10 – 15 lbs.
PCNB + polyram	10-10	3 – 5 lbs.	5 – 10 lbs.	10 – 15 lbs.
PCNB + folpet	10-10	3 – 5 lbs.	5 – 10 lbs.	10 – 15 lbs.
PCNB + captan EC			2 – 4 pts.	
PCNB + thiram EC			2 – 4 pts.	
PCNB + OM-2424 EC			2 – 4 pts.	
PCNB + 126B EC			2 – 4 pts.	
Lanstan EC			2 – 4 pts.	

*Follow directions on container labels.

history of seedling disease in certain areas of their fields and not in others. These differences are due to environmental conditions.

Temperature and Moisture — Temperature and moisture are the two most critical conditions for seedling disease development. Of these, temperature has the greater effect (*56*). Studies under both greenhouse and field conditions have been made at various institutions on the effect of soil temperature and moisture on the development of soreshin (*2, 9, 12, 13, 14, 24, 30, 40, 41, 56*). Personnel of the Louisiana Agricultural Experiment Station have made a 4-year study on the effect of soil temperature on cotton emergence and seedling diseases, and a report of the study is to be published shortly.

Temperature plays an important role in the time required for cotton seeds to germinate and the seedlings to emerge (*4, 20, 40*). The minimum temperature for the germination of high quality upland cottonseed is 53° F. (*20*), with the optimum at 85° - 95° F. (*40*).

In Arizona (*21*) and the mid-South (*40*) a temperature of 65° F. or above was found to be necessary for good seedling growth.

In Texas high quality seed can be planted when the soil temperature at 8-inch depth has a 10-day average of 65° F. (*13*).

Rhizoctonia solani can grow over a relatively wide temperature ranging from 41° to 91° F. (*39*). The fungus can infect cotton over a range of temperatures, with an optimum of 63° - 73° F. (*1, 2, 56*). It has been shown that soil temperature is one of the more important factors affecting the capacity of various isolates of *R. solani* to infect cotton seedlings (*9, 14, 33, 42*).

Other Factors — Among other factors that can aggravate or be confused with cotton seedling diseases are: cottonseed deterioration (*7*);

excess nitrogen (*55*); plant parasitic nematodes (*27, 38*); insect infestations (*26*); calcium deficiency (*58*); combined soil chemicals (*11, 37*); and mechanical injuries (*21*).

The cause and control of cottonseed deterioration and its influence on cotton seedling disease has been discussed.

When nitrate nitrogen reaches a concentration of over 300 ppm in the soil about a cotton plant, delayed germination, injury, or retarded growth may occur. When concentrations are increased, the amount of injury increases. To avoid this injury, nitrate nitrogen should be drilled into the soil about 6 inches to the side of the seed drill (*55*).

A number of experiments have shown that in certain soils where nematode infestations were high, the incidence and severity of soreshin were greater than where nematode infestation was low (*27, 38*). Chemicals for control of nematodes should be used only after it has been established, through soil analysis, that a nematode problem exists.

Where thrip infestations were severe, young cotton plants became more susceptible to seedling diseases (*26*).

Calcium deficiency on cotton seedlings can cause symptoms that appear similar to those of seedling root rot, and pre- and post-emergence damping-off. Calcium deficiency seems to be most severe after heavy rains on light, sandy soils when high temperature and light intensity are coupled with moderately cool, night temperatures (*58*).

Cotton seedlings that were injured by some mechanical means, such as hail, farm equipment, and sand-blasting, tended to be more susceptible to seedling diseases (*21*). Mechanical injuries should be avoided wherever possible.

In recent years observations have shown that certain systemic insecticides used in conjunction with certain fungicides and/or herbicides and under certain environmental conditions, result in seedling diseases more severe than where no chemical was used or where each was used alone (*1*). The use of certain soil fungicides will help to reduce losses where a combination of herbicide and insecticide is used (*11, 37*). Consult specialists before multiple soil chemical applications are attempted.

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Cold Protection for Louisiana Strawberries

Harry J. Braud, Jr. **P. L. Hawthorne**

Louisiana State University and
Agricultural and Mechanical College
Agricultural Experiment Station
Doyle Chambers, Director

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Cold Protection for Louisiana Strawberries

HARRY J. BRAUD, JR., AND P. L. HAWTHORNE[1]

Introduction

Frost and freezes in late February and March in the Louisiana strawberry area can cause much damage to the early berry crop. While cold damage is not necessarily permanent, the loss of the first blossom and fruit crop is very costly due to the favorable market for early berries. Although temperatures moderate as the season progresses, the commercial area has been known to have freezes as late as mid-April.

Cold weather is now the primary cause of early fruit crop losses. The chance for losses from other causes has been reduced by advances in insect control, disease control, plant breeding, and other sciences. Man is unable to control weather on a large scale. However, certain extremes of weather can be modified on field size tracts with available resources and mechanical equipment. The use of wind machines in orchards and the burning of smudge pots to avert cold damage are examples. Irrigation spray has been used successfully for the protection of several kinds of vegetable and fruit crops from cold damage.

In 1962 the Agricultural Engineering Department in cooperation with growers in the commercial strawberry area began a series of studies to evaluate cold protection methods that would be applicable to the Louisiana strawberry area. Growers at that time expressed interest in the cold protection methods in use in California, Michigan and Florida.

With the advent of black plastic for mulching strawberries there was interest in the effect of soil heat on the temperature of the air layer over a field. In the spring of 1962 a comprehensive study was made to evaluate the performance of irrigation sprays and heated-air blowers to control the temperature above and below plastic and straw mulches. The studies were conducted over a broad range of local climatic conditions in three test fields in the strawberry belt. In 1963 and 1964 further studies were made of the use of water sprays for cold protection.

The results of the cold protection are presented here. Because of the success of the sprinkler irrigation method in preventing cold damage, recommendations are made for its use.

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[1] Assistant Professor, Agricultural Engineering Department, and Professor, Horticulture Department.

Temperature Conditions During the Berry Season

The commercial strawberry acreage in Louisiana comprises portions of Ascension, Livingston, St. Helena, St. Tammany, Tangipahoa and Washington parishes (Figure 1). This area has slightly rolling to flat terrain with native pine forests. In late winter, the weather is alternately influenced by continental cold air masses from the north and northwest and relatively warm tropical air masses from the Gulf of Mexico to the south. Lake Ponchartrain exerts a local moderating influence on the climate in areas just north of the lake.

The critical weather period is the late winter and early spring season when strawberry plants are loaded with blossoms and immature fruit. This period includes the last weeks of February and the months of March and April. Frosts prior to the bloom stage do no apparent permanent damage to the plants. Blossoms and fruit appear to be fully susceptible to cold damage.

Frost and freeze conditions follow the arrival of a continental cold air mass, usually characterized by wind shifting from southerly to

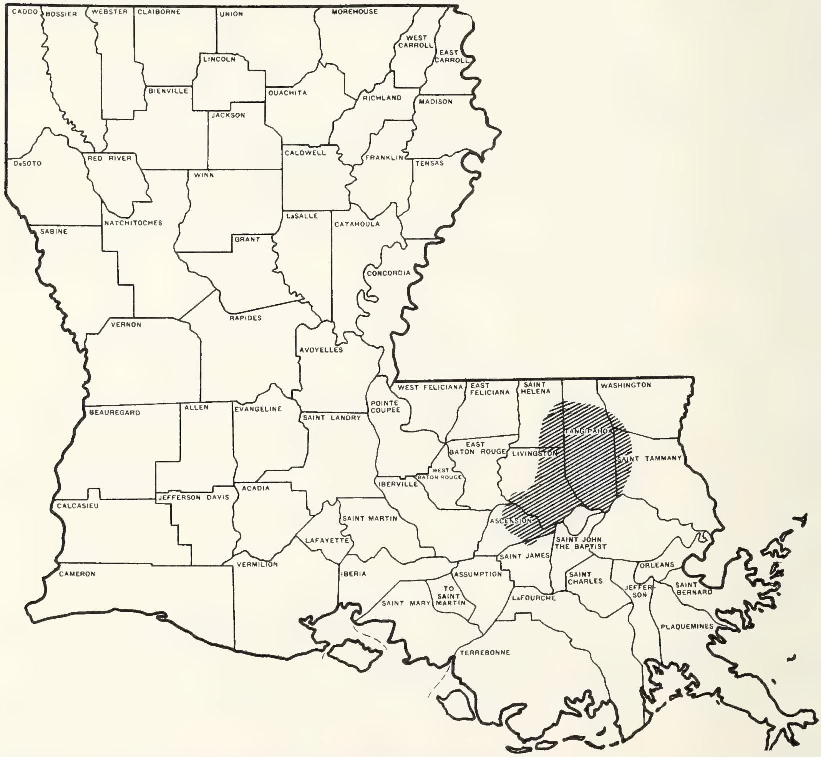

FIGURE 1.—The commercial strawberry producing area is located mainly in Livingston, Tangipahoa and neighboring parishes.

TABLE I.—Chance for Occurrence (Per Cent) of Certain Minimum Temperatures at Hammond, Louisiana

Temperature, °F	Chance for Occurrence In February	March	April
	Per Cent	Per Cent	Per Cent
37 or lower	100	82	54
32 or lower	97	70	6
27 or lower	70	18	0
22 or lower	21	0	0
17 or lower	9	0	0

[1]Based on 33 Years of Record.
Source: United States Weather Bureau (*23*)

westerly to northwesterly and by a sudden drop in air temperature. Winds are brisk northerly and northwesterly following the arrival of the frontal line. The lowest temperatures usually occur at dawn on the first and second mornings after the arrival of the cold front. Cold damage to exposed berry plants results from the combined radiant cooling by exposure to the cold upper sky and the chilling of the cold air mass surrounding the plants. If skies are clear and wind velocity is low, frost can be expected anytime the air temperature drops below 35° F. By late March the heat stored in the soil is usually sufficient to prevent frost damage to berries unless the air temperature falls to 32° F or lower. However, damaging frosts have occurred as late as mid-April in the strawberry area.

As the winter season ends, the sun's path in the sky gradually lengthens and gives more hours of sunshine to warm the earth, which in turn warms the lower atmosphere. The incidence and severity of freezes decrease gradually throughout late February and March. The late freezes which do occur are very costly due to the large quantity of fruit on the plants at that time.

Dense pine forests surround many strawberry fields and provide some sheltering effect near the trees. The edges thus protected experience less frost kill than the areas in the center of a field. Forested tracts have a moderating influence on temperatures following a sudden change in weather. Because the ground is shielded by the dense, overhead vegetation, the soil and the lower air layers in a forest cool more slowly than bare ground areas. The sheltering effect of tall trees is usually limited to the areas immediately adjacent to the trees, usually less than a hundred feet or so from the forest edge.

The Occurrence of Low Air Temperatures

It is not possible to predict precisely what weather extremes will occur during the critical season; however, excellent weather records for several weather bureau stations in the berry area are available for study of past seasons. Weather bureau records for 20 or more years give an

TABLE II.—Dates in Spring of Last Freeze for Five Chances of Occurrence

Station	Dates in Spring After Which Chance of Freeze (29-32°F) Is 75%	50%	35%	20%	10%
Baton Rouge	February 9	February 23	March 3	March 13	March 22
Bogalusa	February 28	March 10	March 16	March 23	March 30
Clinton	March 6	March 15	March 19	March 25	March 31
Covington	February 20	March 4	March 11	March 19	March 26
Franklinton	March 8	March 18	March 24	March 30	April 6
Hammond	March 5	March 15	March 20	March 26	April 2
Springville	February 26	March 8	March 13	March 21	March 27

Source: United States Weather Bureau (*25*)

indication of the weather conditions that have occurred in the past and serve as our best guide for planning to meet conditions in the future. Based on past weather records, probability levels can be developed of the occurrence of certain likely weather conditions and of the not-so-common but extremely damaging conditions such as late freezes, which have been known to occur.

Air temperature is not the sole criterion of the severity of freeze conditions, but cold damage inevitably results when air temperature is below 30° F. When soil temperatures are low, frost damage can occur with air temperature as high as 38° F. Based on 33 years of weather records, the frequencies of certain minimum air temperatures at Hammond are shown in Table 1. The data can be interpreted as follows:

> A temperature of 37° F or lower has occurred in the month of February in 33 out of 33 years of record. Freezes (32° F or lower) have occurred 6 per cent of the years in the month of April. In 9 per cent of the years a temperature of 17° F or lower can be expected at Hammond in the month of February.

The air temperature listed in the table is that recorded in a standard weather bureau shelter several feet above ground level.

For several stations in the vicinity of Hammond the weather bureau has tabulated the latest dates in spring for which freezes can be expected to occur. Table II gives the date for the latest spring freezes for 5 chances of occurrence. For example, at Baton Rouge there is a 75 per cent chance that a freeze will occur as late as February 9. The chance for a freeze after March 22 is only 10 per cent or 1 year in 10. Hammond can expect a freeze as late as April 2, with probability of 1 year in 10.

At Covington a killing frost has occurred as late as April 21 (Table III). The weather bureau defines a killing frost as the condition in which air temperature recorded in the standard shelter is 32° F or lower. For the various stations in the strawberry area it can be seen that low temperatures have been known to occur throughout the month of March and even as late as mid-April.

TABLE III.—Average and Latest Dates of Last Killing Frost in Spring at Four Stations

Station	Length of Record, Years	Average Date of Last Frost	Latest Date of Last Frost
Amite	38	March 16	April 11
Covington	35	March 7	April 21
Franklinton	18	March 9	March 31
Hammond	34	March 8	April 4

Source: United States Weather Bureau (*23*).

TABLE IV.—Lowest Temperature on Record During February, March, and April in the Strawberry Area

Station	No. Years of Record	Month		
		Feb.	March	April
		(Degrees F)		
Amite	42	1	21	28
Clinton	40	0	23	31
Covington	38	10	26	31
Hammond	36	1	22	32
North Livingston	5	10	19	31

Source: United States Weather Bureau (*24*).

Table IV gives the lowest temperature recorded at several stations during the month of January, February, March and April. Note the extreme low temperatures which have occurred in the past. In February and March the lowest temperature for the month usually occurs at the beginning of the month.

Summarizing, one can say that cold conditions can occur throughout the critical berry season. As improved cultural practices such as the use of plastic mulch and improved varieties promote early maturity of the berry crop, the threat of cold weather damage is more predominant. Throughout the month of February freezes can be expected at regular intervals. Even in March frost is not unseasonal but seasonal in most of the berry area. In any one year there is no assurance that the weather conditions will not be as cold or even colder than in past years of weather record. The risk of cold damage will always be great especially in the critical early part of the berry season.

Duration of Cold Temperatures

A night with cold temperatures lasting for many hours is more destructive to vegetation than is one with cold lasting for only a few hours. The soil cools more slowly than the air above it. While air temperature may drop rapidly, the soil temperature changes only a few degrees per hour. This lag in soil temperature prevents the ground from freezing overnight under most weather conditions in the Louisiana strawberry area except for periods of prolonged windborne freezes.

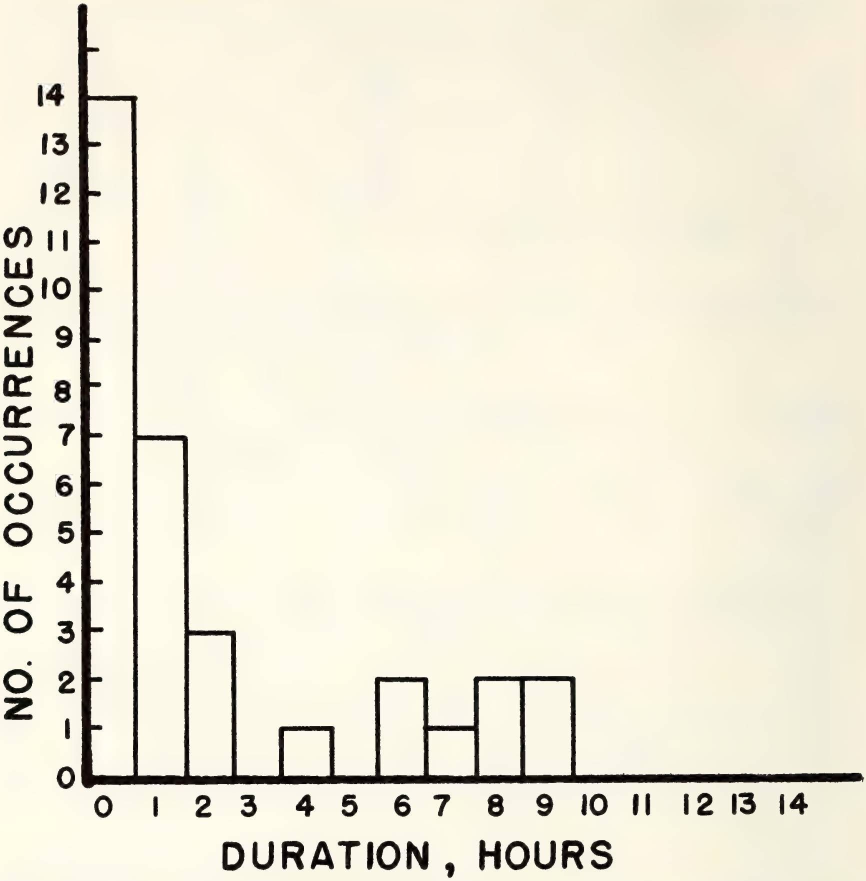

FIGURE 2.—Duration of temperature 30° or lower for all morning freezes February 15 to May 1 in all years 1946 to 1964 at Baton Rouge. Only days with freeze (32° or lower) in the morning hours were included. A total of 32 freezes occurred in the selected period.

In order to estimate the fuel and material requirements for cold protection it is necessary to have some idea of the duration of low air temperatures to be expected during the critical berry season. The duration of low temperature periods can be tabulated from weather records for stations which record air temperature on an hourly basis. The Baton Rouge station, where the climate is somewhat similar to that of the berry area, has records of hourly temperatures for the period of years 1946 to 1964. To ascertain the duration of early morning low temperatures in the berry season, a frequency distribution was compiled for all days from February 15 to May 1 when air temperature was 32° F or lower in the years 1946 to 1964 at Baton Rouge. The number of consecutive hours in which temperatures were below

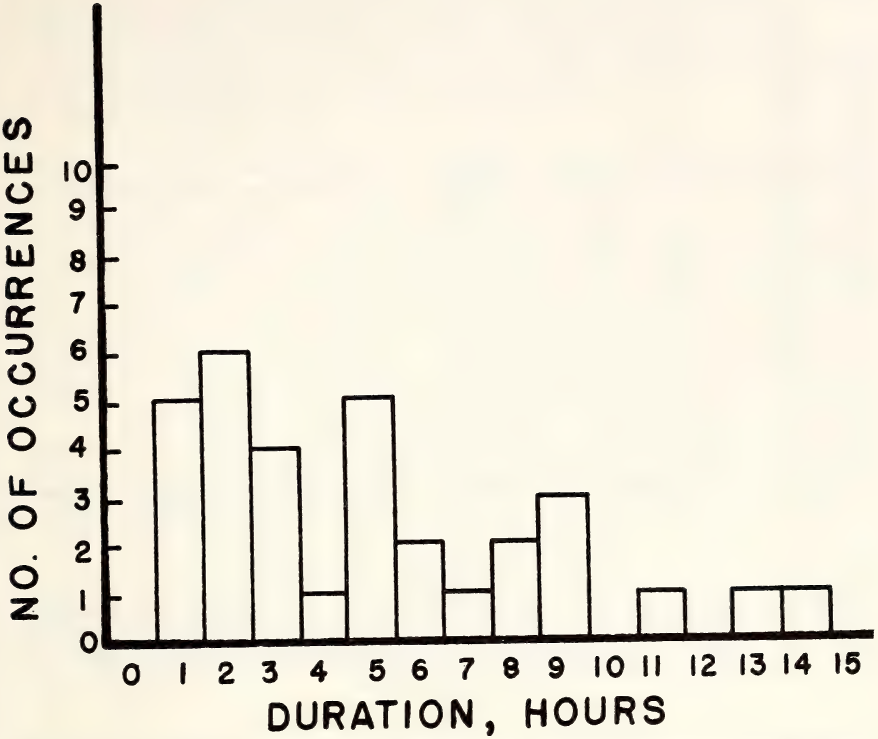

FIGURE 3.—Duration of temperature 32° or lower for all morning freezes February 15 to May 1 in all years 1946 to 1964 at Baton Rouge. Only days with freeze (32° or lower) in the morning hours were included. A total of 32 freezes occurred in the selected period.

36° F was counted for each day with a minimum temperature of 32° F or lower in the morning hours. Only days with morning freezes were used. The count also included the number of hours in which the temperature remained below 30°, 34° and 36° F.

In the 19-year period there were 32 days with freezes (minimum of 32° F or lower) in the February 15 to May 1 interval, or an average of 1.7 freezes per year. Figures 2, 3, 4 and 5 contain a graphical presentation of the frequency distribution of days with temperatures on or below the four selected levels. As is shown in Figure 2, the number of occurrences of freezes with minimum temperature below 30° F is small. In no case did the temperature remain below 30° F for more than 9 hours. The number of freezes (32° F or lower) for more than 10 hours is also small (Figure 3). In only one case did the temperature remain below freezing for as much as 14 hours. The data compiled for occurrences of 34° F for given durations are shown in Figure 4 and for 36° in Figure 5.

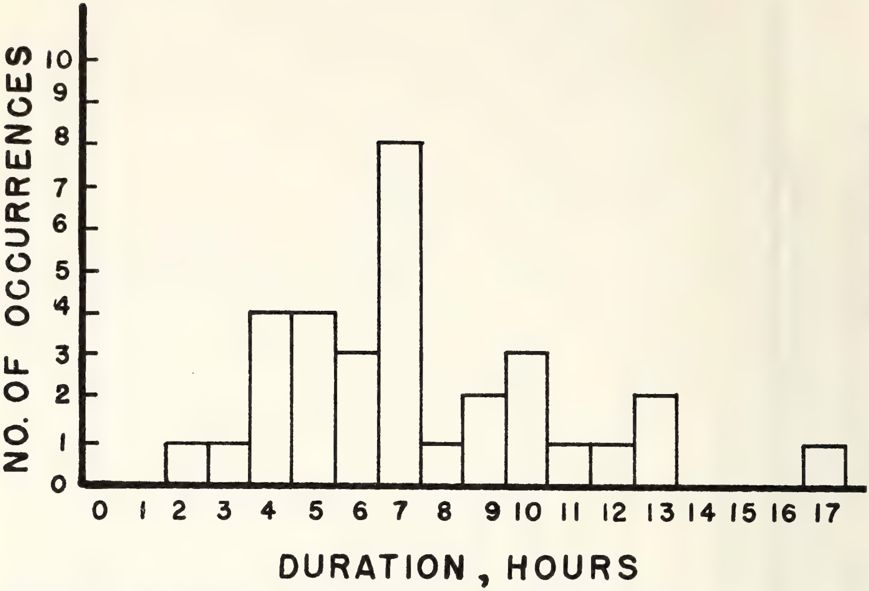

FIGURE 4.—Duration of temperature 34° or lower for all morning freezes February 15 to May 1 in all years 1946 to 1964 at Baton Rouge. Only days with freeze (32° or lower) in the morning hours were included. A total of 32 freezes occurred in the selected period.

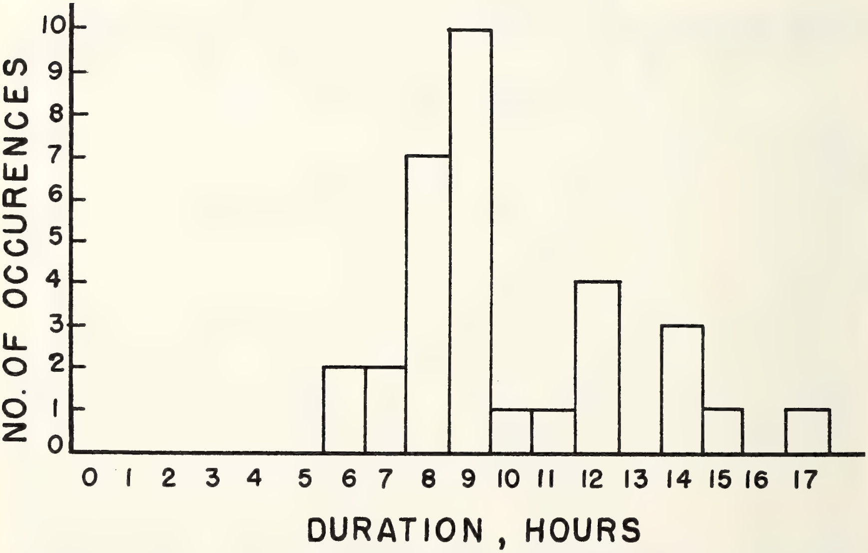

FIGURE 5.—Duration of temperature 36° or lower for all morning freezes February 15 to May 1 in all years 1946 to 1964 at Baton Rouge. Only days with freeze (32° or lower) in the morning hours were included. A total of 32 freezes occurred in the selected period.

In the late winter season, freezes are usually of short duration. Bright, early morning sunshine warms cold surfaces as soon as the sun's rays hit them. The air temperature likewise rises soon after the sun rises. Ice melt due to direct solar heating is often noticed before air temperatures rise above the freezing point.

Atmospheric Conditions Which Cause Cold Damage

The most common measure of atmospheric condition is the temperature of the air near the surface of the earth. Human comfort is directly related to air temperature, for the air which surrounds us determines to a large extent our sensation of being warm, cold, or comfortable. Plants are influenced by the air temperature, but other elements of the environment are equally significant. Wind speed, humidity of the air, and exposure to warm sun or cold upper sky all affect the thermal well-being of a plant. The mass of air which surrounds us always contains some water vapor which can often be seen to condense to liquid water on relatively cold surfaces. Dew is the result of natural condensation of water vapor in the atmosphere. The air is almost completely transparent to the passage of light and radiant heat. This transparency allows heat from the sun to reach the earth with only negligible absorption by the atmosphere. Clouds, however, absorb radiant energy and thereby shade the earth from the heat and light striking them.

Radiation Frost

The transfer of heat from a source such as the sun to another object such as the earth takes place by the process called irradiation. Heat or thermal energy travels by direct rays from the source to all objects which are cooler than the source. Any body warmer than its surroundings will radiate heat. The rate at which heat is liberated depends upon the temperature difference between the warmer body and the colder one. One can be comfortably warm in direct sunshine on cold winter days due to the reception of direct thermal radiation from the sun. The radiation heat transfer process is an important factor in the warming of the soil in the spring.

When the sun sets, there is no heat source in the sky. The upper atmosphere is extremely cold as heat is not stored in the thin dry air. The effective temperature in outer space is estimated by Brooks (2) as 50° F below zero. On cloudless nights the earth is cooled by the process of radiant cooling. Because of this cooling, dew condenses on solid surfaces when atmospheric humidity is at a sufficient level. All solid objects exposed to the sky are cooled when they lose heat by direct radiation to outer space (Figure 6). On extremely clear nights the rate at which objects lose heat by radiation is as high as 25 BTU per hour per square foot of surface (2).

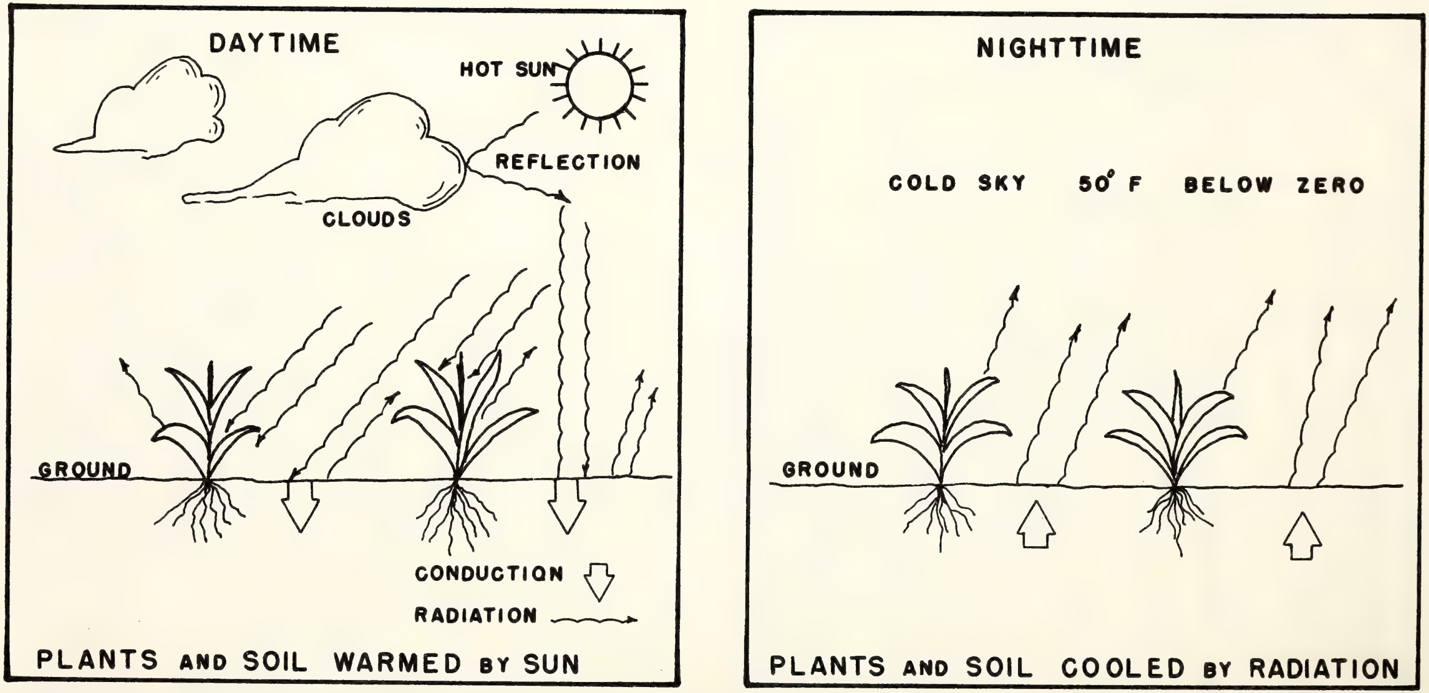
DAYTIME
HOT SUN
REFLECTION
CLOUDS
GROUND
CONDUCTION
RADIATION
PLANTS AND SOIL WARMED BY SUN
NIGHTTIME
COLD SKY 50° F BELOW ZERO
GROUND
PLANTS AND SOIL COOLED BY RADIATION

FIGURE 6—Diagram of heat flow during the daytime and on clear nights. The sun heats the ground by direct radiation and by reflection from clouds. At night plants and the surface of the ground lose heat to the cold upper sky by radiation.

When air temperature is in the 30s radiant cooling can often cause the formation of frost. Moisture in the atmosphere, upon striking the solid surfaces changes to ice crystals, a visible indication of the presence of frost. Frost can form on solid objects such as berry plants, roofs, automobile windshields, etc., even though air temperature measured a few feet above ground is above the freezing point. When there is no wind, radiation cooling can cause the temperature of solid surfaces to drop to the freezing point or lower. Frost has been observed with air temperature as high as 37° F.

When the ground surface cools at night because of exposure to the clear, cold sky, it in turn cools the air layer very near the ground. As the air cools, it becomes heavier and a cool heavy layer clings near the earth. If there is little or no wind, the cool air remains like a blanket over a field. This process is called inversion. The magnitude of this temperature variation under still, clear, dry conditions is

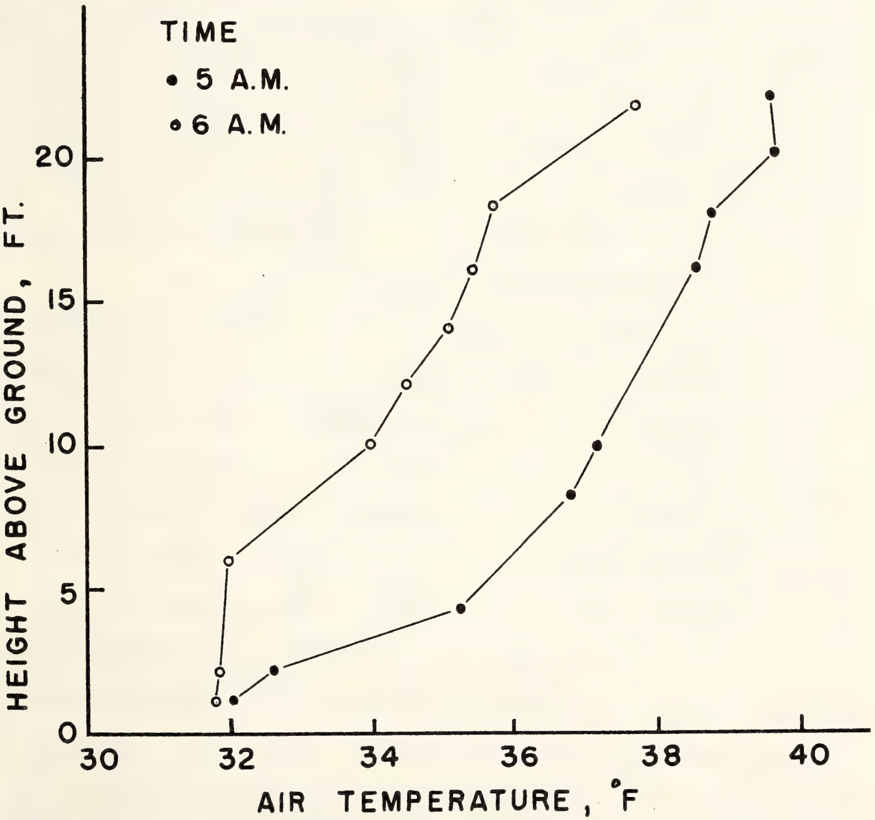

FIGURE 7.—An inversion condition. The tendency of cold air to remain near the surface of the ground is shown here. Measurements of air temperature at different levels made at Baton Rouge, February 16, 1962. in an open field.

TABLE V.—Typical Temperatures of the Air and Exposed Surfaces Under Radiation Frost Conditions, March 22, 1963

	Time, a.m.			
	2:30	3:30	4:30	5:30
		(Degrees F)		
Shielded Air Temperature 24 inches above ground	42	36	34	34
Shielded Air Temperature 2 inches above ground	41	34	32	32
Temperature of Exposed Surface	34	29	27	26

shown in Figure 7 from observations at Baton Rouge for a typical radiation frost morning.

When the wind blows, the air near the ground mixes with the upper air and prevents a pronounced blanket of cold air from remaining over a field. This mixing destroys the inversion process and, for this reason, frost is never observed as long as air temperature is above freezing and the wind is blowing. A wind speed of 4 miles per hour or more prevents thermal stratification so that the temperature of air near the ground is almost the same as the temperature several feet above the ground. This mixing of air layers brings warm upper air in contact with the solid objects near the ground and tends to equalize surface and air temperatures.

A thermometer 5 or more feet above ground gives a poor indication of temperatures very near the ground under still air conditions. True air temperature is commonly measured with a mercury thermometer inside a well-ventilated shelter with the thermometer shielded from radiation heating or cooling. A standard weather bureau shelter, mounted 4 feet or more above ground level, senses the air temperature at that height. To most persons this indication of air temperature is a most meaningful interpretation of the thermal conditions of our surroundings. It serves a useful purpose for many interests even though exposed surfaces are usually several degrees colder.

The radiant cooling of a solid object is often enough to decrease its temperature as much as 8° below air temperature, as shown in Table V. This contrast between air temperature reading and the effective temperature of objects in an exposed field vividly demonstrates the effect of radiant cooling of objects near the ground.

A thermometer or thermostat used in a field to sense the thermal state of objects near the surface of the ground should be fully exposed to the sky. It should be placed in the center of the field away from overhead trees or other material which may shield it from the cold sky. A mercury thermometer on the porch of a house may read 10°

F higher than true temperatures in the critical zone in even an adjacent field.

The temperature of exposed vegetation will be as low or lower than air temperature measured several feet above ground. Any time air temperature is expected to fall to the middle thirties frost is eminent.

Figure 6 illustrates the combined factors which cause frosting of a plant when the air is still.

Freezes

Frost conditions often occur when air temperature is above 32° F, the freezing point of water. When very cold air masses flow into an area, air temperature drops, especially at night when radiant cooling of the earth takes place. A "freeze" is said to occur when air temperature is 32° F or lower. Freezes occur during the berry season of Louisiana although they usually last for only a few hours in the early morning. When air temperature drops, the temperature of plant tissue usually follows closely. Once the temperature of leaf surfaces reaches 32° F, ice crystals appear unless air humidity is very low or there is a brisk wind. The chilling effect of the cold air combined with radiant cooling can inflict severe damage to plant tissue. This extreme condition occurs when air temperature is below freezing and the atmosphere is clear and still. Although frost can occur without a freeze, it is the combination of the two that provides the extreme hazard. In Louisiana, freezes seldom occur without accompanying frost conditions.

The Cold Tolerance of Berry Plants

The leaves and stems of the strawberry plant are able to endure a very low temperature, but the blossoms and fruit are highly susceptible to cold damage. Many factors influence the degree of injury inflicted upon a plant by low temperatures. The stage of development of the fruit crop, the amount of leaf cover over the blossoms and fruits, and the general health of the plant are all known to affect its susceptibility to injury by cold weather. The length of time the temperature remains low, wind speed, cloud cover, and other variables of climate also are significant in the chilling of plants. Careful observation has shown that damage to blossoms and fruits can occur with air temperatures above 32° F. Damage to blossoms and fruit is known to occur when ice crystals due to frost or freezing are observed on the plant material. The actual freezing temperature of the plant material itself is below 32° F due to concentration of soluble materials in the cell sap. Air temperature of 32° F may however damage green fruit and exposed blossoms. Ripe fruit with a higher sugar content may withstand cold temperatures slightly better than young green fruit.

Relatively little information can be found in the literature on the critical plant material temperature for strawberry blossoms and fruit.

It is likely, however, that berry blossoms when fully open are alike in susceptibility to cold as pear, apple, and other delicate fruit blossoms, whose cold tolerance has been more widely studied. Young (*30*) reported the minimum air temperature to which the deciduous blossoms in several stages of development could be exposed for 30 minutes or less. In the full bloom stage apples, pears, and plums could withstand 28° F. The actual temperature of the bloom itself was not reported. The temperature index was air temperature in a standard shelter. The tolerance of blossoms to cold temperatures for longer periods is probably less than for short periods.

Rodgers *et al.* (*19*) used thermocouples inserted in blossoms to learn the actual temperature of plant matter under cold conditions. It was found that a blossom could survive as long as its temperature remained above 29° F. Coit (*7*) noted cold damage when air temperature is 30° F or lower. Most researchers on the use of water sprinkling conclude that water sprinkling should be initiated when sheltered air temperatures fall to 34° F. This level provides a safety margin in protecting delicate tissue against cold damage and reasonably compensates for radiation cooling.

A more realistic interpretation of the cold stress on plants is specification of a minimum temperature measured by a thermometer fully exposed to all forms of atmospheric cooling. A minimum safe temperature can then be defined as the lowest temperature measured near the ground in full exposure to radiant cooling for which fruits and blossoms in the most susceptible stage would experience little or no injury. Rodgers (*20*) recommends beginning water sprinkling when the temperature indicated by a fully exposed thermometer falls to 32° F. In view of the magnitude of the radiant cooling of plants on still, clear nights, the temperature of an exposed thermometer would best serve as a guide for cold protection since it accommodates the temperature depression due to radiation cooling by exposure.

Review of Cold Protection Methods

Cold damage to plants can be prevented by regulating the atmospheric factors which contribute to the chilling of the plant. The soil, a natural heat reservoir, is able to counteract some of the cooling potential of the atmosphere by releasing heat stored during the day. The use of mulch for soil heat retention is widely known. Frost control involves regulation of the atmospheric conditions which cause radiation cooling of exposed objects. This can be accomplished with fog, smoke, or water droplets injected into the air over a field to shield the plant from exposure to the cold upper sky.

The prevention of freeze damage requires the addition of heat directly to the air over a field or the distribution of water spray which releases heat upon freezing. Under certain conditions wind machines can be used to mix warm upper air layers with cold layers near the ground. Some cold protection practices both add heat and reduce the cooling potential of the atmosphere. An example is the burning of smudge pots to heat the air and release smut particles which shield objects on the ground from exposure to the cold sky.

Air Heaters and Wind Machines

Probably the first method for fighting cold damage was the use of air heaters (*2*). Brooks (*2*) reported that in 1959 one third of the California citrus orchards were equipped with air heaters. As many as 25 small heaters per acre are required for effective heating. The high labor and fuel requirements for heaters have caused them to lose popularity in favor of wind machines.

Air heating has been attempted in the Louisiana strawberry area in the past with little or no success. Reports of growers who built wood fires or burned automobile tires in the field indicate that perhaps too few fires were used or the fuel supply was inadequate for continuous heating overnight. It is conceivable that air heating could raise field temperatures to a safe level if enough heat were added to the field environment. However, this practice would be hard to justify economically with the present costs of fuels, labor and equipment.

In certain geographic areas damage to crops is caused by cold air drainage into mountain valleys. Wind machines and air heaters can be used to modify the chilling effect of the influx of cold air if layers near the ground can be mixed with warm upper air layers. The inversion process caused by cooling of the ground by radiation and subsequent chilling of air layers near the ground can be counteracted by the mixing of air layers with wind machines. They are widely used in California orchards in combination with air heaters (*3, 9*). Wind machines are less effective for low growing crops than for orchards.

In recent years machines have been developed which combine a high output heater with a strong fan to blast warm air over a field area. The machines rotate slowly to give full circle of coverage. Advantages claimed for these machines are low labor requirements and a large area of coverage. The machines are portable and can be drawn with a tractor. The coverage afforded by each machine is as high as 2 acres, depending on the type of terrain.

Shields

Shields or covers of plastic, paper, metal cans, etc. are effective in preventing cold damage to plants when they are properly used. The shield should be large enough to cover a plant without touching the plant. Radiation cooling chills the shield to the extent that any part of the plant touching the shield is cooled to the temperature of the shield. Shields must be removed each morning to prevent scalding when the sun rises. The labor needed for covering and uncovering the plants has made shields impractical for commercial field production of strawberries.

Cold Protection With Irrigation

The use of water spray for cold protection of tomatoes was reported as early as 1912 by Roe (*18*). Irrigation systems for cold protection have been used in California and Michigan for many years. Lehmann (*16*) reported the use of frost protection sprinklers for vineyards in Germany. It was noted that sprinkler heads should rotate at least once every 2 minutes to insure continuous wetting of the plants. Protection was achieved with temperatures as low as 21° F by using an application rate of 1/10 inch per hour.

Gray (*12*) emphasized the importance of high water pressure for breaking up spray droplets leaving the nozzles. The droplets in the atmosphere shield the plants from the cold sky. According to Gray a one-tenth of an inch per hour application rate is standard in California for still air conditions. Low growing plants can bear the weight of ice accumulations for application rates as high as two-tenths of an inch per hour. Schultz and Parks (*21*) found that an irrigation rate of 0.08 of an inch per hour was insufficient for cold protection. This application rate could raise leaf temperatures to only 29° F when air temperature is in the lower twenties. Uniformity of application is difficult to achieve with very low application rates.

For conditions of wind accompanying freezes, little data can be found on the water application rates needed. However, Gerber and Harrison (*11*) present an analytical analysis of the heat losses from a thin leaf in a cold air stream. Their analysis suggests an application rate three to four times greater for a 5 mile-per-hour wind than for a no wind condition with air temperatures in the lower twenties.

How Sprinkling Prevents Cold Damage

When water is sprayed over a field, the tiny droplets drift through the air and eventually fall to the earth. The presence of the mist in the air reduces the radiant cooling of plants by shielding them from the cold upper sky. The relatively warm droplets which fall upon vegetation wet the surfaces and warm them by virtue of the sensible (contained) heat in the water. The heat content of water is 1 British Thermal Unit per pound of water per degree Fahrenheit. When 1 pound of water cools from 50° to 32° F, 18 BTU of heat is released to the surroundings. The freezing of water involves a change from liquid to solid with the libration of 144 BTU per pound of water. Thus, the cooling of 1 pound of water from 50° F to solid ice requires the removal of $18 + 144 = 162$ BTU from the water. It can be seen that the freezing process releases more heat than the cooling of water from 50° F to the freezing point.

If air temperature near the ground is below 32° F, ice forms on plant surfaces as long as water spray is added. The temperature of the ice-water mixture remains at 32° even though the surrounding air may be colder than 32° F. The continuous addition of liquid water supplies available heat to counteract the losses due to atmospheric cooling. Success of the water spray method depends upon the continuous application of spray throughout the cold period and until morning temperatures rise to melt all accumulated ice.

Studies of the rate of heat loss to the atmosphere by Brooks (2) indicate that radiant cooling due to exposure to clear cold skies amounts to 25 BTU per hour per square foot of surface. To counteract this loss, water must be added, which releases heat upon freezing, at a rate to maintain temperatures at 32° F. For air temperatures of 26° F with no wind, an application rate of one-tenth of an inch per hour is generally sufficient to maintain plant leaf temperatures near 32° F, which is a safe temperature. For lower air temperatures several investigators recommend an increased application rate.

Cold Protection Studies

Cold Protection With Sprinkler Irrigation

The 1962 Season

In order to evaluate sprinkler irrigation methods for cold protection in the Louisiana strawberry area, sprinkler systems were installed in two fields in the Ponchatoula area in the late February of 1962 prior to the first blossom crop that year. Fields were designated A and B for identification. A was a 6-acre field with pine forests on the east and south sides and 1,000 feet of open exposure to the north and west. It had plastic-mulched berries on a silt loam soil. B was an 8-acre field surrounded by forests on all sides. The test area was in the southernmost portion of this field. Berries were straw-mulched in this field on medium to heavy silt loam soil. The check area for both fields was chosen to the north of the area to be sprinkled so that any spray drift due to wind would not carry onto the check area.

Data were obtained on March 5, 6, 7, and 16. Following the arrival of a cold front in the berry area on March 4, the air temperature began to fall from the middle fifties to the mid-twenties. Three mornings with frosts followed. A late cold air mass brought frost again in mid-March.

Sprinkler Studies (Field A)—The equipment for field A was selected to give an application rate of about 0.11 of an inch per hour. Sprinklers were placed on an 80x80-foot spacing and 5/32x1/8-inch nozzles were used. An alarm thermostat was placed in the field to sound an alarm bell when temperatures of the exposed thermostat dropped to 34° F. The water supply was a small open reservoir filled by two 2-inch wells. Water temperature in the reservoir remained near 50° F.

Temperature Measurements: A 16-point recording potentiometer was installed in the field to monitor the effective temperature in the sprinkled and check area (Figure 8). The recorder scanned 16 locations at a rate of

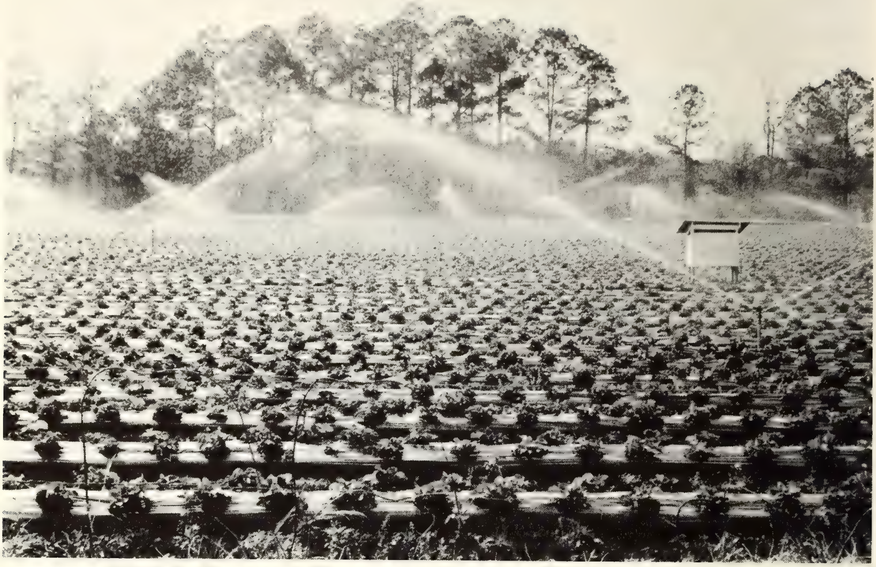

FIGURE 8.—An instrument shelter was placed in the test field to house the temperature recorder. Thermocouples with leads up to 120 feet long were used to sense temperatures over a broad area in both the sprinkler-protected and check areas. All temperature data were recorded continuously with the automatic recorder.

1 point every 2 minutes. Temperature was sensed with copper-constantan thermocouples soldered to a 1/32x1x6-inch brass clip coated with lampblack paint and mounted horizontally 4 inches above the ground in full exposure to radiant cooling. Clips were randomly distributed in the sprinkled and check areas to give sensing points in each area. Air temperature was measured in a sheltered location 3 feet above ground. The temperature of the dull brass clip mounted horizontally at berry plant height was defined as the effective temperature resulting from the combined influence of convective air cooling and radiation exchange with the upper sky above and the mulched soil below. Figures 9 and 10 show the type of instrumentation used.

During early morning hours on March 5, air temperature dropped to 32° F by 4 a.m. Effective temperature in the field was near 30° F. With clear skies and no wind the exposed surfaces were cooled by outgoing radiation to 28° F by 5 a.m. Visible frost crystals began to appear on plant leaves, and the water was turned on at this time. Visible frost in unprotected areas remained on the plants until the sun rose at 7:30. Sprinkling was continued until the sun melted accumulated ice. Table VI gives the clip temperatures in the sprinkled plot and the check area. Air temperature 3 feet above ground is also listed for comparison.

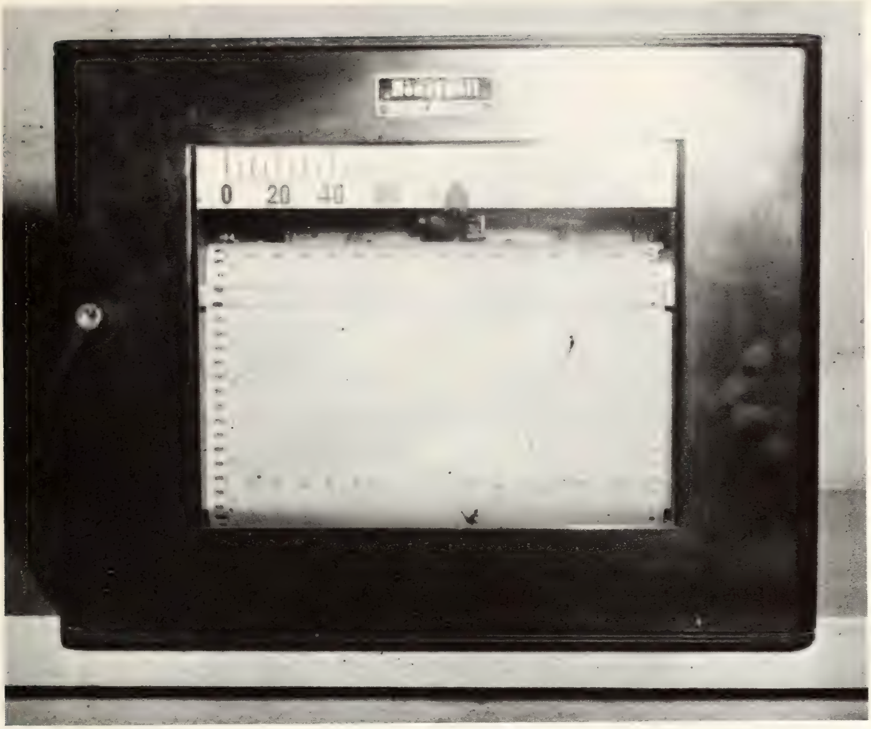

FIGURE 9.—An automatic temperature recorder. Sixteen different temperatures can be monitored by the recorder. The chart drive is synchronized with the time of day and gives continuous temperature records.

Note that effective temperature of radiantly cooled surfaces was as much as 7 degrees below air temperature. A thin ice layer developed on the plants. With the application of 0.11 of an inch of water per hour the effective temperature in the sprinkled area remained at 34° F, 2 degrees above freezing. According to Gray (*12*) a sprinkling rate of 0.10 of an inch per hour is adequate for temperatures in the mid-twenties.

TABLE VI.—Effective Surface Temperature at Berry Plant Height and Air Temperature for Moderate Frost Conditions, March 5, 1962

	Time, a.m.				
	5:00	5:20	5:40	6:00	6:20
			(Degrees F)		
Sprinkler Protected	33.0	34.0	34.0	34.0	34.0
Check Area	28.7	27.0	27.0	29.0	29.8
Air Temperature 3 Ft. Above Ground	33.0	34.0	32.5	34.0	41.0

Note: 1. Application rate of 0.11 of an inch per hour.
2. Each surface temperature is average of eight observations.

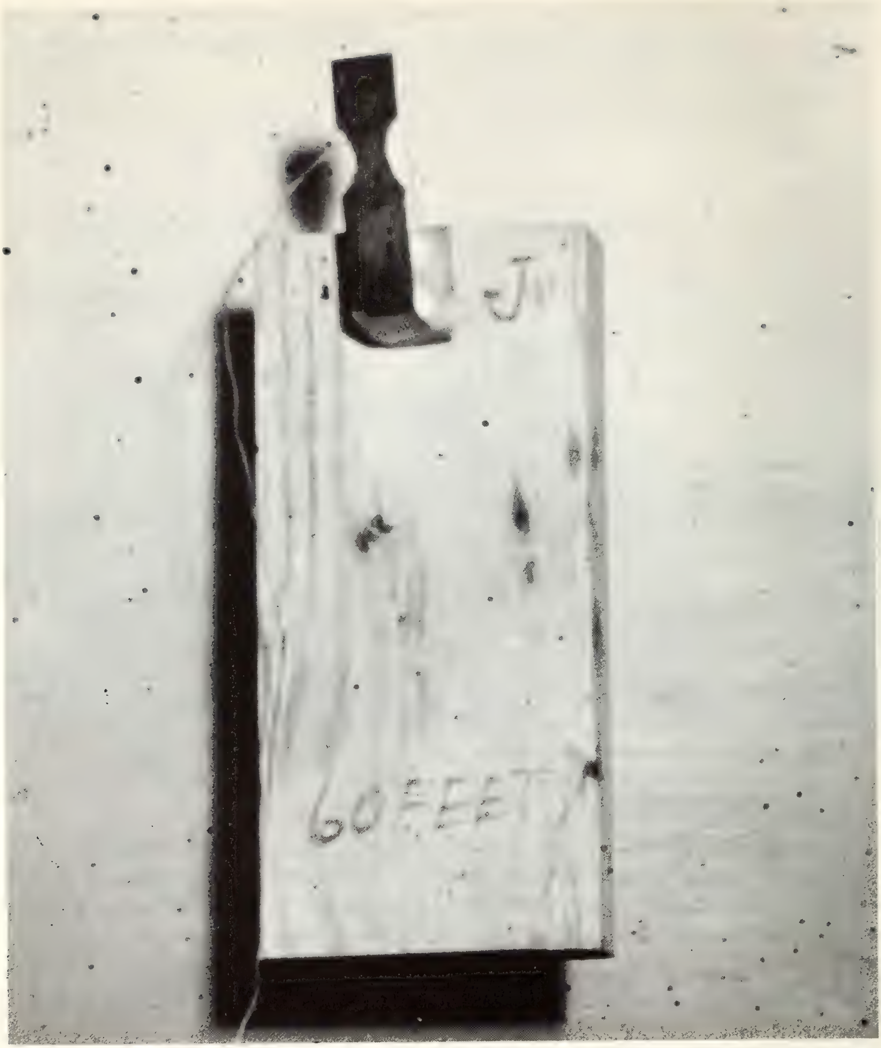

FIGURE 10.—Brass clip with thermocouple soldered to underside. The clip was mounted on wooden block to support the sensing element in a horizontal position with the element directly over mulch material The temperatture experienced by the thin, black brass strip is the effective surface temperature.

In order to evaluate the effectiveness of a lesser application rate in the test field the 5/32-inch nozzles were replaced by 1/8-inch nozzles, which gave an application rate of 0.09 of an inch per hour.

The most severe freeze occurred on the morning of March 6. Although temperatures rose to the upper fifties during the day of the fifth, a lingering mass of cold, dry air brought freezing conditions early

TABLE VII.—Effective Surface Temperature at Berry Plant Height and Air Temperature for Freeze Conditions, March 6, 1962

	Time, a.m.								
	12:15	12:30	12:45	2:00	3:00	4:00	5:00	6:00	7:00
	(Degrees F)								
Sprinkler Protected	28.4	29.3	33.6	34.0	34.2	33.0	33.0	32.3	33.9
Check Area	24.5	25.1	24.1	24.5	22.7	20.8	22.6	22.8	26.2
Air Temperature 3 Ft. Above Ground	31.2	30.2	30.1	29.0	28.8	27.6	29.2	30.3	30.3

Note: 1. Application rate 0.09 of an inch per hour.
2. Each surface temperature is average of eight observations.

that night to the local area. By 11 p.m. on the fifth, air temperature fell to freezing. The clear, dry air promoted radiation cooling to the extent that effective field temperatures dropped to 27° by 11 p.m. When the water supply was turned on, heat release of the freezing water immediately raised effective temperatures to 32° in sprinkled areas. The lowest air temperature (3 feet above ground) recorded was 28° at 6 a.m., but effective temperature in unprotected plots dropped to 21° at some locations. Table VII gives a tabulation of temperatures recorded in the sprinkled and unprotected plots for that night. With 7 hours of continuous operation of the sprinkler system, ice thickness on plants was about 1/4 of an inch.

With 80x80-foot spacing of sprinklers in field A, it was found that 45 pounds per square inch pressure was inadequate to give proper coverage to center areas most distant from the sprinklers. A slight blackening of strawberry foliage due to cold damage was observed where the water coverage was known to be inadequate.

A light freeze with severe frost conditions occurred again on the morning of March 7. Sprinkler equipment was turned on at midnight when air temperature was still above freezing, although effective temperature had dropped to 27°. Under milder freeze conditions, sprinkling at a rate of 0.09 of an inch per hour was sufficient to prevent any ice or frost accumulation on plants. As is shown in Table VIII, air temperature barely fell below the freezing point although radiation cooling chilled solid surfaces to 24°. Temperatures recorded during the three day cold period indicated that an application rate of 0.09 of an inch per hour was sufficient for freezes with no wind and temperatures as low as 27° with severe radiation cooling conditions. The freezes were on days following warm weather. These freeze conditions did not represent the extreme cold to be expected in the berry area. Since it is difficult to achieve uniform water distribution at very low application rates, it is not recommended that a rate of 0.09 of an inch per hour be used. To obtain adequate coverage and uniform water distribution, the application rate should be greater.

TABLE VIII.—Effective Surface Temperature at Berry Plant Height and Air Temperature with Sprinkler Protection, March 7, 1962

	Time, a.m.				
	12:00	4:00	5:00	6:00	7:00
			(Degrees F)		
Sprinkler Protected	34.2	33.9	34.0	34.4	34.9
Check Area	26.7	24.7	25.1	26.9	33.4
Air Temperature 3 Ft. Above Ground	32.2	32.1	30.3	32.0	35.0

Note: 1. Application rate 0.09 of an inch per hour.
2. Each surface temperature is average of eight observations.

Blossom Damage Counts: Following the 3-day cold period, a count of blossom and green fruit damage was made in the sprinkled and check areas in the test field. Table IX presents the percentage damage observed by visual count. A random selection of about 20 plants in each area was used for inspection for cold damage. Individual blossoms and fruits on plants were counted and examined. Cold damage produces blackening of the skin on green fruit and complete blackening of the inner staminate portions of a blossom. The general viability of the plants was also observed. The water sprinkling was very effective except in areas where sprinkling was known to be inadequate. None of the plants under full sprinkler protection showed leaf burn or other signs of cold damage. In the unprotected areas, some cold damage was observed in the crown of plants. In unprotected areas, the loss of first blossoms and fruit delayed fruit harvest a full 3 weeks.

A moderate frost occurred again on March 16. Sprinkler irrigation, begun at 6 a.m. and operated for an hour, provided excellent protection. The strawberry plants in the sprinkled plot had a heavy crop of green berries at this time. No loss of green fruit or blossoms was noted in the sprinkled plot. The unprotected berries had lost the first fruit crop to previous cold damage. The second blossom and fruit crop suffered some damage on March 16 in the check plots.

The ultimate success of the sprinkler protection was proven when the protected strawberry plants produced the first ripe fruit a full 3 weeks before unprotected plants in the same field.

TABLE IX.—Strawberry Fruit and Blossom Damage with Sprinkler Protection

	Per Cent Fruit and Blossoms	
	Damaged	Not Damaged
Sprinkler Protected	0	100
Check Area	86.3	13.7

Note: Damage based on visual observation of number of fruits and blossoms showing signs of cold damage on green fruits and blossoms open at time of frost on three mornings preceding day of count. In each field, twenty or more plants were chosen at random to furnish samples for count.

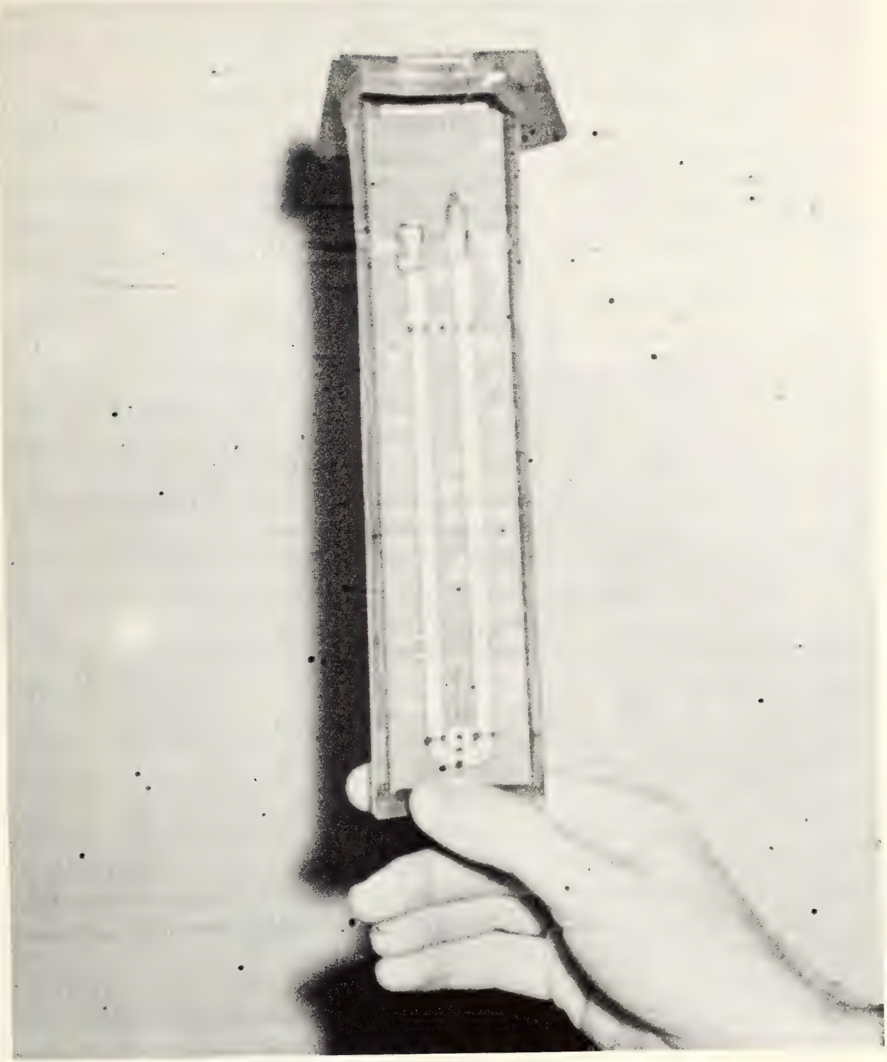

FIGURE 11.—A maximum-minimum thermometer. When mounted on a row in the field with bulb exposed to radiant cooling the temperature reading was used for effective surface temperature.

Sprinkler Studies (Field B)—In field B, equipment was available for coverage of 2 acres with sprinklers on a 40x60-foot spacing with 5/32-inch single nozzles. When operated at 30 pounds per square inch this gave an application rate of 0.13 of an inch per hour. An open pond provided a water supply.

Maximum-minimum thermometers (Figure 11) were used for detecting temperatures because there was no power supply in the field for automatic recorders. The thermometers were placed at random throughout the sprinkled and check areas. The thermometers were placed on top of the rows, well exposed to radiant cooling, and were read each hour by an observer. It was found that the effective temperature given by a thermometer with an exposed bulb was similar to that given by a thermocouple clip mounted in the same position.

On the morning of March 5, the sprinkler system was operated for about 2 hours in the field. Water was turned on when visual observation showed ice crystals on the plants. No temperature records were made that morning.

The sprinkler system was turned on at midnight on the sixth when effective temperature fell to 30° F and ice crystals were observed on the plants. The system was operated until 7 a.m. Table X gives results of sprinkler irrigation at the 0.13 of an inch per hour rate used in that field.

TABLE X.—Effective Surface Temperature Two Inches Above Strawberry Row with Sprinkler Protection March 6, 1962

	Time							
	11:30 p.m.	12:30 p.m.	1:30 a.m.	2:30 a.m.	3:30 a.m.	4:30 a.m.	5:30 a.m.	6:30 a.m.
	(Degrees F)							
Sprinkler Protected	28	33	33	33	33	33	33	33
Check Area	28	27	26	25	24	24	24	26

Note: 1. Temperature measured with exposed thermometer.
2. Sprinklers were started at 12 midnight.

The application rate of 0.13 of an inch per hour was effective in preventing cold damage to blossoms and fruits. The lowest temperatures recorded in the sprinkled areas was 33° F. A slushy ice accumulation was observed wherever the spray drip accumulated.

The sprinkler system was operated again on the morning of the March 7 for several hours. No temperature records were made since adequate data had been collected on the previous morning.

A count of blossom and fruit damage following the 3 days of cold protection indicated that the application rate of 0.13 of an inch per hour gave a high degree of protection. In the check area the entire blossom and fruit crop was lost in contrast to 5.5 per cent loss in the sprinkled area (Table XI).

No automatic alarm was available for detecting low temperatures in this test field. The water application based on visual observation of frost was delayed 1 hour in comparison to the application in field A with its automatic control. Had the water been applied sooner each night, it is assumed that 100 per cent protection would have been achieved.

TABLE XI.—Strawberry Fruit and Blossom Damage with Sprinkler Protection

	Per Cent Fruit and Blossoms	
	Damaged	Not Damaged
Sprinkler Protected	5.5	94.5
Check Area	100	0

Note: Damage based on visual observation of number of fruits and blossoms showing signs of cold damage to green fruits and blossoms open at time of frost on three mornings preceding day of count. In each area, 20 or more plants were chosen at random to furnish samples for count.

The 1963 and 1964 Seasons

During the 1963 season five strawberry growers used irrigation for cold protection. Automatic temperature recorders similar to the one used in 1962 were placed in two fields. One field was in the northernmost portion of the strawberry belt where the coldest temperatures were expected. An application rate of 0.10 of an inch per hour was used for the field. Another field had a system designed to give an application rate of 0.05 of an inch per hour in one area, 0.10 of an inch per hour in another, and 0.20 of an inch per hour in a third location.

Because of unfavorable winter weather, the berry crop was late that year with the first blossom crop coming in mid-March. A light frost occurred on March 22 and 23 following several warm days. Temperatures in the field did not fall to the critical level until about 5 a.m. each morning. All the growers who operated their systems reported no cold damage in the protected areas. In the test field where the three different application rates were used all systems were equally effective in preventing cold damage under the light frost conditions. In the unprotected areas damage was estimated to be 25 per cent of open blossoms and fruits. Because of the exceptionally warm days preceding the frost days, the heat storage in the soil was sufficient to prevent extensive damage even in unprotected areas.

A review of the temperature records for the test fields gave convincing evidence of the effectiveness of water spray for averting frost damage. For mild frost conditions a light application rate is usually effective. However, because of the difficulty of altering an irrigation system once it is set up in the field, the application rate should be such that the extreme cold condition can be accommodated.

The 1964 berry season was little troubled by cold weather except for a few nights when air temperature fell to the middle thirties and high cloud cover suppressed radiation cooling sufficiently to prevent frost formation. One grower, who had a sheltered field, had berries in bloom by February 20. He operated a sprinkler system with complete success for three nights in succession. The low air temperatures for the three nights were 29°, 20°, and 28° F. An application rate of 0.13 of an inch per hour was sufficient with air temperature as low as 20° F and intense radiation cooling conditions. This low temperature, although rare in late February, gave the most severe cold condition for the evaluation of sprinkler protection in the Louisiana area.

Conclusion

There is a possibility that a windborne freeze with temperatures below 20° F will occur in the berry season of late February and March. The lowest temperatures of the day may occur during early morning for a short period of time. As was shown in Table II, there is only a 9 per cent possibility for a 17° F or lower temperature in the month of February at Hammond. The occurrence of low temperatures decreases rapidly as the month progresses.

The results of studies reported herein indicate that an application rate of 0.13 of an inch of water per hour can be recommended for cold protection for the Louisiana strawberry area. This rate should give adequate protection for the low temperatures for even the coldest seasons. An application rate of 0.10 of an inch per hour is generally accepted in other areas as adequate for air temperatures in the twenties. The increased rate gives added protection for lower air temperatures and for light wind movement. Even for severe freeze conditions it is felt that a high degree of protection will result from the 0.13 of an inch per hour application rate.

The Performance of Heated-Air-Blowers

The question has been raised as to whether heater-blower machines along with sheltering effect of pine forests which surround many of the Louisiana strawberry fields, would effectively protect strawberries from cold damage. It was believed that the insulating effect of the forest surrounding a field would enhance the heating of a field area by the addition of heated air. The 1962 season provided an opportunity to observe the performance of heater-blowers in use in a berry field surrounded by a dense pine forest which offered excellent insulation from air drifts.

The layout of the field is shown in Figure 12. Each heater-blower consisted of a diesel burner with a fuel consumption of about 10 gallons of No. 2 diesel fuel per hour. The blower was powered by a 25 hp air-cooled gasoline engine.

Effective temperature at berry plant level was measured with maximum-minimum thermometers placed on the row and read each hour by an observer. The machines were put into operation starting shortly before midnight on March 6 and operated until sunrise. The results of temperature measurements are shown in Table XII. The area around the machines in which effective temperature remained above 29° F was very small. The radius of a 1-acre circular area is 117 feet. It can be seen that each heater-blower was able to protect less than 1 acre of

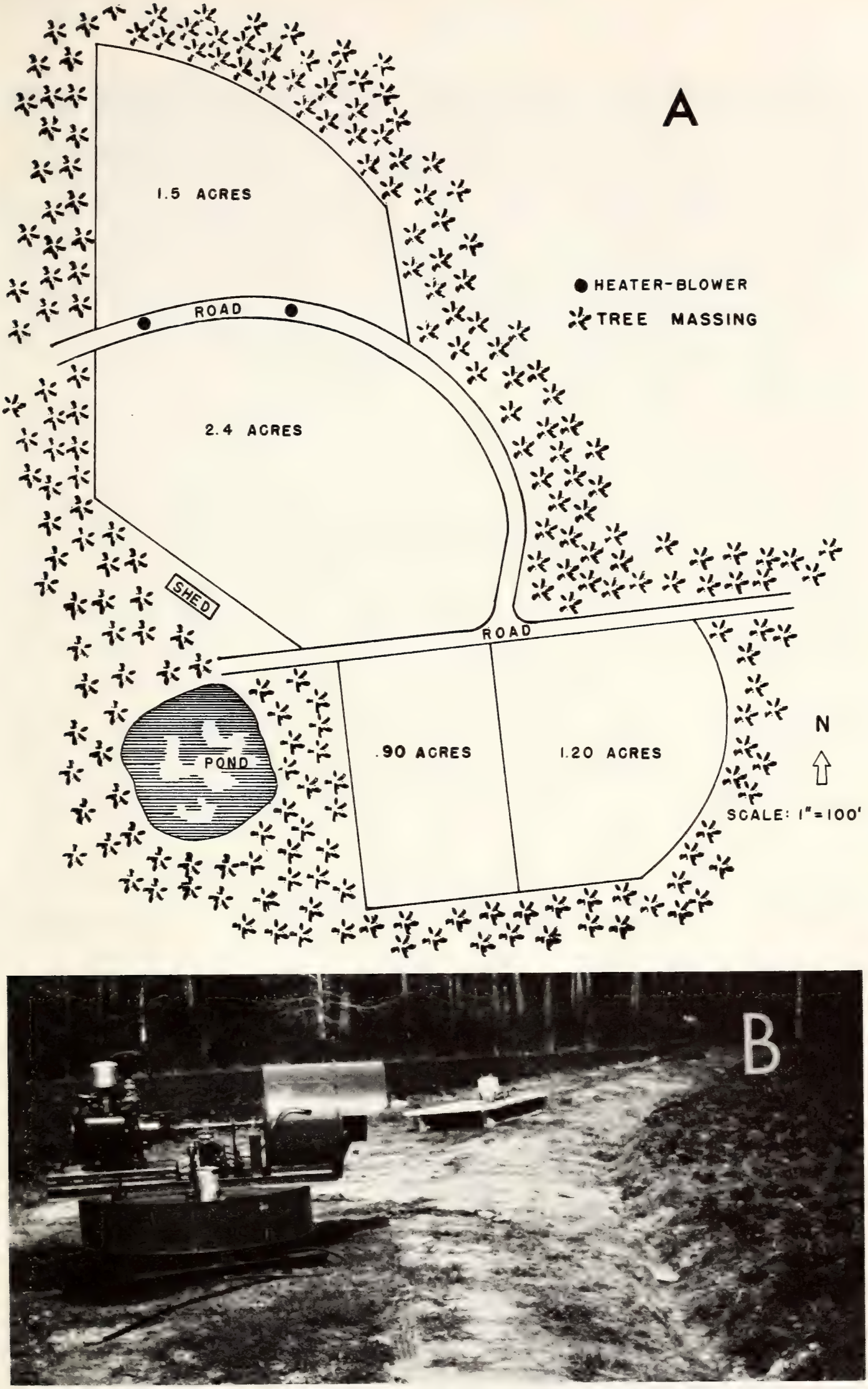

FIGURE 12.—(a) Layout of field showing location of heaters. Dense pine forests surrounded the field on all sides. (b) A heater-blower of the type used in the study. A gasoline engine drives the fan with a diesel-fired burner in the air stream. The machine rotates slowly to give a full circle of coverage.

field. A larger concentration of heaters would be needed for freeze protection for temperatures in the lower twenties. Plants within a 30-foot radius of a heater were severely damaged from apparent excessive heating. A count of blossom and fruit damage in the field correlated very closely to the observed temperature distribution in the field (Table XIII). For mild freezes or moderate frost conditions when upper air layers are not too cold, the heated-air-blower probably would offer some degree of protection to berry plants. For moderate frost and freeze conditions the heated-air-blower can protect only a small area. At this time the use of these machines cannot be recommended for Louisiana conditions.

TABLE XII.—Effective Temperature Two Inches Above Strawberry Row with Air Warming by Two Heater-Blowers

Location In Field	Time 11:30 p.m.	12:30 p.m.	1:30 a.m.	2:30 a.m.	3:30 a.m.	4:30 a.m.	5:30 a.m.	6:30 a.m.
	(Degrees F)							
100 Ft. S. of Heaters	27	29	29	26	26	26	26	29
150 Ft. from Two Heaters	26	30	28	28	27	27	28	29
200 Ft. S. of Both Heaters	28	29	28	27	26	26	27	28
300 Ft. S. of Both Heaters	26	29	26	26	25	25	26	26
Check Area	26	27	25	25	24	24	24	26

TABLE XIII.—Strawberry Fruit and Blossom Damage in Field with Heater-Blower Protection

Distance to Nearest Heater Blower	Per Cent Fruit and Blossoms Damaged	Not Damaged
50 feet	45	55
70 feet	65	35
80 feet	88	12
100 feet	100	0
150 feet	100	0

Note: Damage based on visual observation of number of fruits and blossoms showing signs of cold damage on green fruits and blossoms open at time of frost on three mornings preceding day of count. In each area, 20 or more plants were chosen at random to furnish samples for count.

The Effect of Plastic Mulch on Temperature Near the Ground

The solar heat absorbed by the ground is slowly released to the air above it at night. The type of mulch material is known to influence the heat gain of the soil and the release of heat to the air above. During cloudy weather little direct solar radiation reaches the ground and the soil temperature tends to approach air temperature. Waggoner, Miller, and DeRoo (*29*) present comprehensive data on soil temperatures under straw, transparent plastic, and black, opaque plastic mulches. Their data show that the solar heat absorption of plastic films is superior to straw for warming the soil during the daytime. At nighttime the release of ground heat to the air is impeded by the insulation effect of pine straw mulch. Several strawberry growers have reported the observation of frost on pine straw-mulched berries several hours before the frosting of adjacent plastic-mulched berries. For very light frost conditions the release of ground heat can delay or even prevent frost formation on plants.

In 1962 a comparison of effective temperatures above plastic and pine straw mulches was made along with measurements of soil and air temperature. Table XIV shows effective temperature for brass clips above ground level on a morning when light frost appeared on the surface of straw mulch. At 6 a.m. temperature was 33.4° above plastic and 30.7° above pine straw. No visible frost was observed on plastic mulch that morning. Blossoms and fruit damage counts showed that some advantage can be attributed to plastic mulch (Table XV). Note that the radiation frost occurred even though air temperature remained above

TABLE XIV.—Temperatures with Pine Straw and with Plastic Mulch for Radiation Frost Conditions, March 13, 1962

Location	Observation Point	Time a.m.					
		4:00	4:30	5:00	5:30	6:00	6:30
		Degrees F					
4 Inches Above Plastic Mulch	P1	38	39.0	35.0	35.5	33.5	32.5
	P2	37	38.0	34.5	35.0	33.0	33.0
	P3	37	36.5	34.0	33.5	32.5	32.5
	Average	37.7	37.8	34.5	34.7	33.4	33.1
4 Inches Above Straw Mulch	S1	36.0	35.0	32.2	31.5	30.5	30.5
	S2	33.0	33.0	31.0	30.5	30.0	29.0
	S3	35.5	34.5	32.5	31.0	31.0	30.0
	S4	36.0	34.5	31.5	32.5	31.5	31.0
	Average	35.1	34.2	31.8	31.3	30.7	30.1
Air Temperature 3 Ft. Above Ground		45	41.0	39.0	37.0	37.0	36.2
Soil Temperature 4" Below Straw Mulch		60.0	60.0	59.5	59.0	59.0	59.0
Soil Temperature 4" Below Plastic Mulch		63.5	63.0	62.5	62.0	62.0	62.0

TABLE XV.—Strawberry Fruit and Blossom Damage with Pine Straw and with Black Plastic Mulch

Type of Mulch	Per Cent Fruit and Blossoms	
	Damaged	Not Damaged
Straw	96.2	3.8
Black Plastic	86.3	13.7

Note: Damage based on visual observation of number of fruits and blossoms showing signs of cold damage on green fruits and blossoms open at time of frost on three mornings preceding day of count. In each field, 20 or more plants were chosen at random to furnish samples for count.

freezing. While plastic mulch does give a slight advantage in warming the air near the ground, it cannot be depended upon to protect plants against cold damage from moderate and severe frost and freezes.

Plastic mulch does have the advantage of storing solar heat during daytime in early spring. This promotes early maturity of the berries. In cloudy weather the effect of plastic mulching diminishes because of the loss of soil heat which allows soil temperature to approach air temperature.

Summary

Sprinkler irrigation for cold protection was evaluated in 2 test fields in the 1962 season. Three application rates were used. It was found that 0.09 of an inch per hour was not sufficient for full protection due to inadequate coverage of field areas in the center of the sprinkler pattern. Another test field where 0.13 of an inch per hour was used obtained excellent protection. Temperature measurements with thermocouples attached to metal strips indicated that the temperature of exposed surfaces remained near 32° F in sprinkled areas when air temperature was in the middle twenties. Blossom and fruit damage counts on the day following 3 mornings of frost and freezes confirmed that an application rate of 0.13 of an inch per hour gave complete protection for the cold conditions experienced in the tests. It was found that a uniform sprinkler coverage is imperative with low application rates.

In 1963, 5 growers used sprinkler protection with satisfactory results. Two fields were instrumented. Only mild frost conditions occurred during the critical period. Application rates of 0.05 of an inch per hour, 0.10 of an inch per hour, 0.20 of an inch per hour were all effective for the light frost conditions.

In 1964 one grower reported success with sprinkler irrigation at a rate of 0.13 of an inch per hour with a low temperature of 20° F and intense radiation cooling. The system was operated three consecutive nights with daily low temperatures of 29°, 20°, and 28° F.

It was concluded that an application rate of 0.13 of an inch per hour can be recommended for the Louisiana strawberry area for cold protection. This rate assures sufficiently uniform coverage of the field. In view of the fact that there is a remote chance for freezes with temperatures below 20° F in the critical early fruiting season, the recommended rate should give a high degree of protection even for these temperatures.

A study of the performance of heater-blower machines operated in a sheltered field was conducted in 1962. It was found that a very small area can be protected with this type of machine. Temperature measurements and blossom damage counts in the vicinity of two machines showed that the area of protection is less than 100 feet in radius. Due to the small area of coverage, the possible plant damage from excessive heat near the fan, and the high fuel consumption rate, the use of heater-blowers cannot be recommended for strawberry cold protection.

Black plastic mulch is superior to straw much for soil heat gain during the day and the release of heat to the air above at night. For very light frost conditions the release of soil heat can delay the frosting of plants several hours. The effective temperature over plastic mulch was observed to be 2 to 3 degrees higher than over pine straw mulch.

Plastic mulch alone cannot be depended upon to protect plants from moderate frosts and freezes. It does however promote early maturity of the berry crop by raising soil temperatures throughout the early season. Its use is recommended for both early maturity and the added advantage of heat release to the plant environment during the cold, early morning hours.

Using Sprinkler Irrigation for Cold Protection

The success of sprinkling for cold protection depends to a great extent upon proper use of the sprinkler system. Unlike ordinary irrigation, sprinkling for cold protection must be done immediately when atmospheric conditions in the field warrant such use. There is no known method for undoing cold damage to plants.

Since frost and freezes usually follow the arrival of a cold front, the general weather conditions should be observed throughout the critical season. Weather bureau forecasts for the nearest station should be noted with proper adjustment for the local area. It should be remembered that general weather forecasts represent the average conditions to be expected at the station. Local variations can be expected. If the forecast calls for the temperatures in the thirties with clear skies, frost conditions may be eminent. When the forecast indicates freezing temperatures, cold damage is likely to result. The mechanical equipment for cold protection should be ready for use prior to the first bloom and left there until mid-April. Although the chance of cold damage diminishes as the season progresses, a late frost can cause severe loss.

Equipment for Cold Protection

Ordinary sprinkling equipment can be used for cold protection. The main requirement is that pressure, nozzle size, and sprinkler spacing be coordinated so that a uniform application of water can be placed over the entire area to be protected. Since portable pipe is usually not purchased in amounts to irrigate a whole field at one time, some additional pipe may be needed for cold protection, or only a part of a field can be protected.

A solid-set or semi-permanent irrigation system is excellent for cold protection use. This method of irrigating is well adapted to strawberries on plastic mulch because the light application rate allows excellent water penetration into the row. The term "solid-set" applies to the method of irrigating which employs small diameter aluminum pipe placed to cover an entire field area at one setting. A reduced application rate is used, which allows a smaller pipe size than is needed for portable sprinkler irrigation. The irrigation rate for solid-set irrigation is the same as that required for cold protection operation. This gives dual usage of solid-set equipment. The grower who is contemplating the purchase of irrigation equipment should investigate the features of solid-set equipment since irrigation and cold protection can be accomplished with the same equipment. The design of solid-set systems is similar to portable systems except that low application rates are used.

The layout of equipment for cold protection is similar to that for sprinkler irrigation. The pipe, power unit, and sprinklers should be selected to give proper performance. Many combinations of pressure, nozzle sizes, and sprinkler spacing can be used for obtaining the proper sprinkling rate. For the Louisiana strawberry area 0.13 of an inch per hour is recommended. Most irrigation equipment manufacturers provide tables to specify sprinkling rates for a range of pressures and sprinkler spacings appropriate for their equipment. Their recommendations should be followed. However, if none are available, the data given in Table XVI will serve as a guide for coordinating sprinkler spacing, operating pressure, and nozzle sizes to give the sprinkling rate

TABLE XVI.—Sprinkler Spacing, Nozzle Size, and Pressure for Cold Protection

Sprinkler Spacing (Feet x Feet)	Gallons Per Minute Per Sprinkler Required	Nozzle Size (Inches)	Operating Pressure (Lbs. Per Sq. In.)
30 x 50	1.9	3/32 Single	40 to 50
30 x 60	2.3	7/64 Single	40 to 50
40 x 40	2.2	7/64 Single	30 to 45
40 x 60	3.2	1/8 Single	40 to 50
60 x 60	4.9	9/64 Single	40 to 60
		5/32 Single	40 to 50
60 x 80	6.3	11/64 Single	40 to 60
		1/8 x 1/8	40 to 50
80 x 80	8.0	5/32 x 3/32	50 to 65
		3/16 Single	50 to 65
		13/64 Single	50 to 65

Note: 1. Closer spacing should be in direction across prevailing wind.
2. GPM for average application rates of 0.13 of an inch per hour.
3. Small nozzles can be used only on small sprinklers to insure proper rotation.

for cold protection. Other investigators have found that sprinkler heads used for cold protection should rotate at least once per minute to insure continuous wetting of the plants. A more uniform application of water can be obtained with a triangular spacing of sprinklers than with a square pattern (Figure 13). If an 80x80-foot spacing is used, the triangular spacing is needed to properly cover areas most distant from a sprinkler. Once the equipment is set up in the field, the pump should be started and the system operated for a few minutes to test for leaks, obstructions in nozzles, etc. Remember that the equipment will have to operate under adverse cold weather conditions. A fuel supply for internal combustion engines should be available for overnight operation. To test the uniformity of application with any sprinkler system, use open-top oil cans placed over the area to be wetted. Measure the depth of spray collected over a known time period—30 minutes, for example.

Water Requirements and Horsepower

A sprinkling rate of 0.13 of an inch per hour requires a water supply of 65 gallons per minute per acre sprinkled, allowing 10 per cent losses. Table XVII gives the water requirements in gallons per minute for sprinkler operation for fields up to 15 acres in size. The horsepower

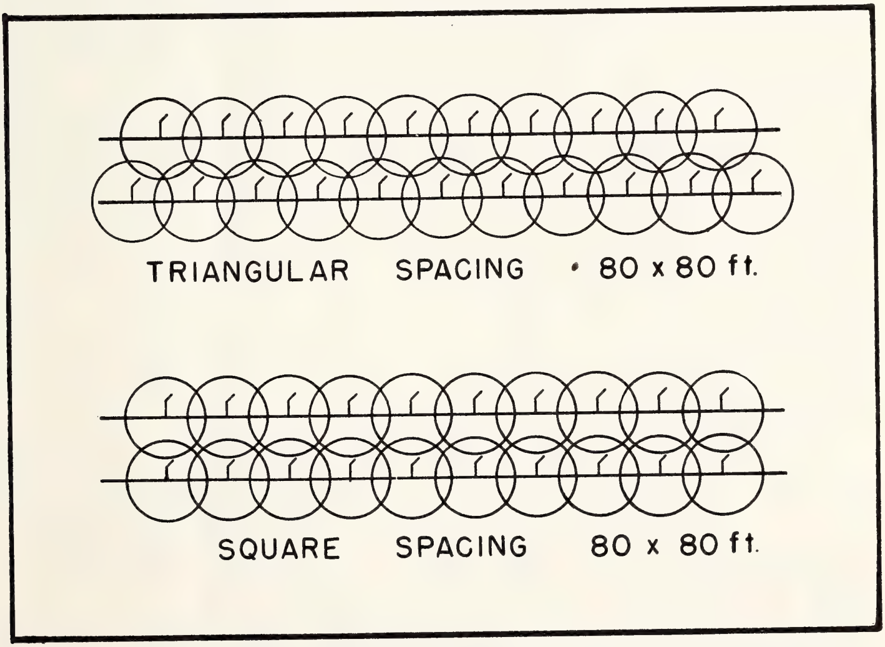

FIGURE 13.—A triangular sprinkler pattern gives a more uniform distribution of water, especially at the wide spacings used for cold protection. If a rectangular pattern is used the closer spacing should be in an east-west direction.

TABLE XVII.—Water Requirements and Approximate Horsepower for Cold Proctection

Size of Field (Acres)	Water Requirements (Gallons Per Minute)	Continuous Horsepower Required
1	65	4
2	130	8
3	195	12
4	260	17
5	325	20
7	455	29
8	520	33
10	650	41
15	975	62

Note: 1. For application rate 0.13 of an inch per hour plus 10 per cent for losses.
2. Based on 60 per cent pump efficiency, 50 psi operating pressure and 10 psi total friction loss, 10 ft. suction lift.

requirements based on 60 per cent pump efficiency and 10 feet of suction lift is also given. These figures serve as a guide in the selection of equipment and are, therefore, general and not to be taken as absolute for the design of all installations.

A sprinkler system pumping directly from a well will operate satisfactorily if the well has sufficient capacity and the power unit is powerful enough to develop the needed pressure for cold protection operation. Since sprinkling for cold protection requires a lesser application rate than ordinary sprinkler irrigation, a system which has enough output for irrigation will suffice for cold protection.

A small capacity well can be used to fill a reservoir to meet the peak requirements for a few hours operation. Assuming continuous pumping from a well, the capacity of the well should be such that 24 hours of well pumping will supply enough water for 12 hours continuous operation of sprinklers. Some seepage and evaporation losses can be expected. As was shown in the discussion of low temperature duration, the period of cold weather seldom lasts longer than 12 hours per night during the critical berry season. If the sprinkler system must be operated several nights in a row the well and reservoir would have to supply a volume of water in 24 hours equal to the amount needed for a night's operation of the sprinkler system.

A reservoir filled by surface runoff can serve as a water supply for sprinkling. The volume of storage in a reservoir is measured in acre-feet. An acre-foot is the volume of water 1 foot deep over 1 surface acre. One acre is 209 x 209 feet, or 43,560 square feet. One acre-foot equals 328,000 gallons. A pond with a 2 acre surface and an average depth of 6 feet contains 12 acre-feet of water (6 feet x 2 acres).

The general requirements for irrigation are one acre-foot of reservoir storage per acre of land to be irrigated. This is adequate for the cold protection operation since reservoirs are usually full following winter rains.

Alarm Bell

The prediction of expected low air temperature given by the weather bureau is the sheltered air temperature several feet above ground. As was pointed out previously, the effective temperature in an an open field will be quite a bit lower if skies are clear and wind velocity is low. A mercury thermometer on a house porch will also give poor indication of the actual conditions even in an adjacent open field. Some sensing device should be placed in the field or at least in an exposed location near the field so that true cold condition can be detected. A mercury thermometer placed on a row in the field will give a fairly accurate reading of cold stress. However, the thermometer must be read often to sense the changes as the night progresses.

A simple thermostatic warning device can be used for sensing temperature near the ground in open exposure. Johnson (*13*) devised an instrument to warn the grower of impending cold conditions. A refrigeration gas-filled thermostat acts as a sensor which switches on a warning bell when the temperature in the field drops to 34° F due to combined atmospheric and radiation cooling. The thermostat is mounted on a board and placed in open exposure away from shielding by trees, buildings, or other cover. When the temperature of the bulb drops to 34°, the bell circuit is energized and sounds an alarm near the sleeping quarters of the attendant. The tube of the thermostat should be painted dull black to remove the metallic shine from its surface. To check the calibration or operation of the thermostat, place it in a home freezer along with a mercury thermometer. The thermostat should make contact when the thermometer reads 34°. A diagram of the thermostat is shown in Figure 14.

Cold Protection Operation

When frost or freeze conditions are expected the grower should go

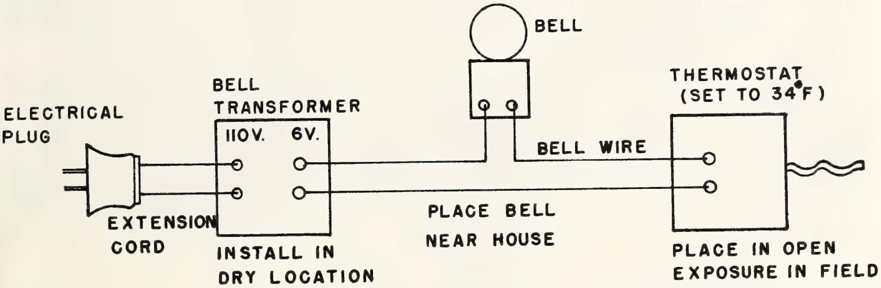

FIGURE 14.—Circuit diagram for thermostat alarm bell. Components consist of a refrigeration-type thermostat with a gas-filled bulb, 6-volt door bell and transformer. The thermostat should be set to sound alarm when temperature drops to 34° F. Mount thermostat bulb in full exposure to radiant cooling.

immediately to the field and inspect the plants for visible frost crystals. A mercury thermometer should be placed on the row open to the sky and a reading taken of the temperatures near the ground. If the temperature is near freezing and continues to fall, the sprinkler system should be readied for operation. The water should be turned on and all sprinklers should be observed to see that none are clogged and all are operating properly. It is necessary that all plants receive the light application of water. If conditions are severe, ice will immediately form on all wetted surfaces. This is necessary to insulate the plants from cold damage. Once the water is turned on, the system should not be turned off until the sun rises the next morning or the weather warms enough to melt ice that has accumulated on the plants. The system must be operated continuously as long as the cold conditions prevail. Do not be alarmed by the ice accumulation on the plants. Once the cold threat has ceased and the water turned off, any water which has accumulated in the furrows should be drained off. Experience has shown that strawberries can withstand a very heavy ice accumulation with no damage to the plants.

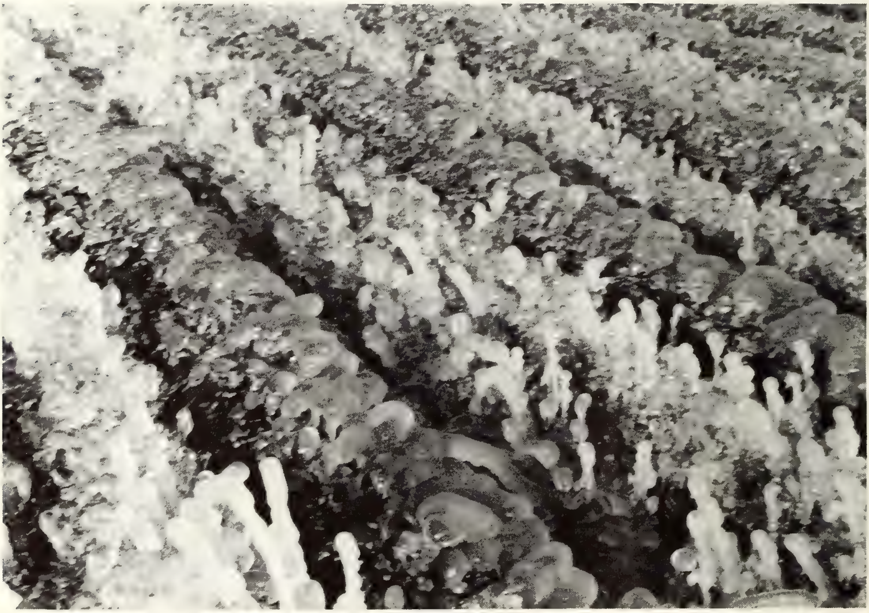

FIGURE 15.—Heavy ice coating on berry plants is necessary to insulate plants from extreme cold. The accumulation of ice is normal and is not harmful to the plants if sprinklers are kept running.

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EFFECT OF SUBMERGENCE ON SEVERAL BIOLOGICAL AND CHEMICAL SOIL PROPERTIES

F. H. REDMAN and W. H. PATRICK, JR.

Agricultural Experiment Station
Doyle Chambers, Director

Louisiana State University and
Agricultural and Mechanical College

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Effect of Submergence on Several Biological and Chemical Soil Properties

F. H. REDMAN AND W. H. PATRICK, JR.[1]

Introduction

Waterlogging of soils commonly occurs in Louisiana because of high rainfall and poor surface and internal drainage of some soils. Soils that are used for rice culture are intentionally waterlogged during most of the growing season. The biological and physicochemical changes that accompany waterlogging, or submergence, are important in determining the suitability of the soil for crop production. The availability of several plant nutrients and the production of toxic substances in the soil are influenced by the restriction in soil aeration resulting from submergence.

The properties of a waterlogged soil are substantially different from those of a well-drained soil. In a well-drained soil there is enough oxygen available from the atmosphere to supply the needs of microorganisms and higher plants. Flooding the soil changes this condition completely. Air movement through the flood water is restricted and the soil no longer has an adequate supply of oxygen. In the absence of oxygen, facultative anaerobes and true anaerobes become active. Reduced organic and inorganic substances are produced. Many oxidation-reduction systems in the soil that are important to the nutrition of plants are affected by the anaerobic conditions that result from waterlogging. Nitrate nitrogen present in the soil is subject to denitrification and loss from the soil. Organic matter decomposition is usually slower and less complete under anaerobic conditions. Combined nitrogen released through organic matter decomposition accumulates in the ammonium form since aerobic conditions are necessary for the microbial oxidation of ammonia to nitrate. Anaerobic conditions also result in the reduction of iron and manganese compounds to more mobile forms. If the reduction is intense enough, sulfate will be reduced to sulfide. Soil pH is also influenced by submergence. The pH values of reduced soils are generally higher and have a narrower range than pH values of well-drained soils.

This study was designed to measure the effect of waterlogging on several biological and physicochemical properties of Louisiana soils that are important to plant nutrition and growth. More specifically, this study involved an investigation of:

(1) Nitrate reduction rates under submerged conditions.
(2) Accumulation of ammonia under submerged conditions.
(3) Accumulation of ferrous iron and manganous manganese in the soil under submerged conditions.
(4) Release of phosphorus from a nonextractable to an extractable form as a result of submergence.
(5) Effect of submergence on pH, redox potential, and specific conductivity of the soil.

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[1] Formerly Graduate Assistant and Professor of Agronomy, respectively.

Materials and Methods

Twenty-six Louisiana soils were used in this investigation. All soil samples were taken from the plow layer of cultivated fields. Information on the cropping systems in the fields from which the samples were taken is given in Table 1. After sampling, the soils were air-dried, mixed, and passed through a 32-mesh sieve. The soil properties pertinent to this investigation are shown in Table 2.

This study was conducted both with and without added organic matter. Organic matter was applied to the soil in the form of ground corn leaves. The rate of application was 0.25 per cent on an air-dry basis.

Nitrate Reduction

The nitrate reduction experiment was designed to measure the rate of nitrate reduction as a result of flooding a moist soil with and without additional organic matter. Eighteen 5-gram air-dry samples of each soil were weighed into 15 x 125-millimeter test tubes and wetted with distilled water to one-third atmosphere moisture values. The samples were incubated for two weeks at 30° C. Nitrate nitrogen was then added

TABLE 1.—Soils and Cropping Systems

No.	Soil	Parish	Crop	Cropping System
1	Commerce	Tensas	Cotton	Cotton, winter cover crop
2	Mhoon	Tensas	Soybeans	Cotton, soybeans, corn
3	Commerce	Tensas	Cotton	Cotton
4	Mhoon	Tensas	Corn	Cotton, soybeans, corn
5	Sharkey	Tensas	Soybeans	Soybeans, cotton
6	Richland (Loring)	Franklin	Cotton	Cotton
7	Olivier	Franklin	Cotton	Cotton, corn
8	Lintonia (Memphis)	Franklin	Corn	Cotton, corn
9	Gallion	Caldwell	Soybeans	Cotton, soybeans
10	Yahola	Rapides	Sugarcane	Sugarcane, cotton
11	Miller	Bossier	Cotton	Cotton, soybeans, corn
12	Yahola	Bossier	Cotton	Cotton, soybeans, corn
13	Yahola	Bossier	Cotton	Cotton, soybeans, corn
14	Sharkey	E. Baton Rouge	Sugarcane	Sugarcane, soybeans
15	Sharkey*	E. Baton Rouge	Fallow	Sugarcane
16	Sharkey*	E. Baton Rouge	Fallow	Sugarcane
17	Sharkey*	E. Baton Rouge	Fallow	Sugarcane
18	Crowley	Acadia	Sudan grass	Rice, pasture
19	Baldwin	St. Mary	Sugarcane	Sugarcane
20	Mhoon	Lafourche	Sugarcane	Sugarcane
21	Baldwin	St. Mary	Sugarcane	Sugarcane
22	Baldwin	St. Mary	Sugarcane	Sugarcane
23	Midland	Acadia	Rice	Rice, pasture
24	Richland (Loring)	Lafayette	Sugarcane	Sugarcane, soybeans
25	Commerce	W. Baton Rouge	Sugarcane	Sugarcane, soybeans
26	Iberia	St. Mary	Sugarcane	Sugarcane

*Formerly classified as Mhoon.

TABLE 2.—Some Chemical and Physical Properties of the Soils Investigated

No.	Name	Sand %	Silt %	Clay %	Texture	Particle density	O.M. %	⅓ Atmos. %	NO_3^-N ppm	NH_4^+N ppm	Fe ppm	P ppm	Mn ppm	pH	Conductivity mmhos/cm.	Eh m.v.[1]
1	Commerce	43.5	42.5	14.0	Loam	2.65	0.95	16.0	1.6	8.5	9.3	437.6	40.1	6.85	0.190	+519
2	Mhoon	4.9	51.7	43.4	Silty clay	2.65	2.41	35.4	18.9	12.0	7.7	375.4	83.8	6.45	0.338	+562
3	Commerce	43.9	40.8	15.3	Loam	2.64	0.79	17.3	4.1	22.2	5.1	347.8	37.9	6.55	0.148	+554
4	Mhoon	9.8	53.3	36.9	Silty clay loam	2.65	2.19	33.8	2.6	7.3	6.4	408.7	74.5	6.60	0.392	+474
5	Sharkey	1.9	22.7	75.4	Clay	2.61	5.24	54.0	38.9	16.7	11.2	425.1	76.3	6.60	0.772	+444
6	Richland	2.6	78.3	19.1	Silt loam	2.62	0.97	27.2	2.4	13.6	4.8	105.0	159.4	6.00	0.129	+601
7	Olivier	3.9	75.7	20.4	Silt loam	2.64	1.27	30.1	1.8	13.4	5.1	195.3	87.9	6.15	0.165	+546
8	Lintonia	7.7	66.7	25.6	Silt loam	2.67	0.89	26.5	2.2	13.7	7.1	96.4	58.1	6.15	0.123	+589
9	Gallion	20.3	68.3	11.4	Silt loam	2.60	0.86	19.2	23.0	11.0	11.1	148.0	16.4	6.10	0.136	+569
10	Yahola	32.6	49.6	17.8	Silt loam	2.64	0.76	18.6	2.9	4.8	6.6	312.1	44.1	7.95	0.270	+461
11	Miller	6.3	47.2	46.5	Silty clay	2.61	2.32	29.9	12.1	9.4	4.5	345.0	59.3	7.65	0.450	+476
12	Yahola	61.8	26.8	11.4	Sandy loam	2.64	0.61	11.1	7.3	7.4	5.0	262.6	21.2	7.90	0.229	+424
13	Yahola	26.7	47.0	26.3	Loam	2.64	1.63	23.7	9.9	3.9	5.1	327.9	57.7	7.90	0.351	+444
14	Sharkey	25.0	39.4	35.6	Clay loam	2.67	1.18	26.9	12.2	5.3	5.5	321.4	49.8	6.95	0.294	+492
15	Sharkey	74.7	13.8	11.5	Sandy loam	2.65	0.88	10.2	6.4	3.6	5.0	344.4	20.5	7.67	0.211	+477
16	Sharkey	2.8	56.0	41.2	Silty clay	2.65	2.43	33.3	96.1	12.8	4.5	245.7	75.2	6.05	0.872	+592
17	Sharkey	41.2	48.3	10.5	Loam	2.65	1.34	20.1	21.6	7.2	5.2	378.0	66.0	6.45	0.273	+582
18	Crowley	10.2	73.1	16.7	Silt loam	2.64	0.78	27.8	5.3	13.9	3.3	6.1	126.6	6.85	0.257	+516
19	Baldwin	12.6	58.7	28.7	Silty clay loam	2.66	1.26	26.6	17.3	44.2	13.4	52.5	34.5	4.85	0.284	+634
20	Mhoon	3.5	62.0	34.5	Silty clay loam	2.68	2.59	36.7	30.4	8.7	5.6	769.6	129.7	6.70	0.520	+491
21	Baldwin	12.8	51.4	35.8	Silty clay loam	2.62	2.38	31.2	43.7	22.3	10.7	381.7	123.8	5.20	0.520	+634
22	Baldwin	2.5	63.1	34.4	Silty clay loam	2.63	2.47	37.0	21.0	40.3	6.1	267.3	116.0	5.50	0.375	+579
23	Midland	3.4	58.6	38.0	Silty clay loam	2.64	1.52	32.6	3.4	10.2	6.7	46.4	76.2	6.65	0.300	+566
24	Richland	1.8	82.7	15.5	Silt loam	2.59	1.56	29.5	61.2	14.9	13.4	42.0	171.0	5.65	0.397	+582
25	Commerce	52.7	38.3	9.0	Sandy loam	2.64	0.61	10.8	11.2	15.8	11.6	393.9	28.1	6.50	0.222	+494
26	Iberia	0.4	25.9	73.7	Clay	2.71	2.46	52.0	12.3	67.7	18.7	75.2	42.6	5.20	0.552	+579

[1] Determined immediately after flooding.

to the soil at a concentration of 250 parts per million and the soil submerged. The submerged soils were incubated at 30° C. and sampled periodically for 32 days. After sampling, the tubes were stored in a freezer maintained at —20° C. until the experiment terminated, at which time all of the samples were analyzed for nitrate nitrogen.

Nitrate nitrogen in the samples was extracted by shaking for 30 minutes on a mechanical shaker with 30 milliliters of distilled water and approximately 0.2 gram of calcium hydroxide. Aliquots of the filtrate were quantitatively analyzed for nitrate using phenoldisulfonic acid. The nitrate reduction rates were calculated by determining the regression coefficient of the equation relating nitrate concentration to length of time submerged. The method of least squares was used for this calculation.

Ammonia Accumulation

The production of ammonium nitrogen under flooded conditions was studied by flooding duplicate 5-gram samples of air-dry soil in 15 x 125-millimeter test tubes with 5 milliliters of distilled water. The samples were incubated for 30 days at 30° C. and then were frozen at —20° C. until analyzed.

Ammonium ions in the samples were extracted by shaking for 30 minutes on a mechanical shaker with 30 milliliters of 10 per cent sodium chloride solution of pH 2.5. Aliquots of this filtrate were quantitatively analyzed for ammonium nitrogen by the direct nesslerization method recommended by the American Public Health Association (*1*).[2]

Iron and Manganese Mobilization

Changes in extractable iron and manganese caused by submergence were studied in an experiment similar to that for ammonia accumulation. Five-gram samples of soil were incubated for 30 days at 30° C.

Iron and manganese were extracted by shaking the soil for 20 minutes on a mechanical shaker with 50 milliliters of normal sodium acetate solution of pH 2.8. The iron extracted was determined by the colorimetric dipyridyl method according to the procedure of Kumada and Asami (*5*). Extractable manganese was determined by a modification of the method developed by Peech *et al.* (*8*).

pH

Fifty grams of air-dry soil were flooded with 50 milliliters of water in a 150-milliliter beaker. The samples were kept at a room temperature of approximately 25° C. Measurements of pH were made at the start (30 minutes after flooding) and at monthly intervals for four months. These determinations were made with a Beckman Zeromatic pH meter with glass and calomel electrodes which had been standardized at pH values of 7.0 and 5.0.

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[2] Italic numbers in parentheses refer to List of References on Page 28.

Specific Conductivity

Seventy-five grams of air-dry soil were flooded with 75 milliliters of distilled water in a 250-milliliter Erlenmeyer flask. The samples were kept at a room temperature of approximately 25° C. Specific conductivity measurements were made at the start (30 minutes after flooding) and after 30 days. Specific conductivity was determined with a U. S. Bureau of Soils electrode cup using a conductance bridge.

Redox Potential

This experiment was designed to measure the redox potential (Eh) of the soil at different times after flooding. Special platinum electrode tubes were constructed by sealing a 1-inch piece of 18-gauge platinum wire in the side near the bottom of 20 x 150-millimeter Pyrex test tubes. Before starting the experiment, the platinum electrodes were cleaned electrolytically in normal hydrochloric acid. This was done by connecting the positive pole of a 22½-volt dry cell battery to a carbon electrode and connecting the negative pole of the battery to the platinum electrode and allowing hydrogen to bubble from the platinum electrode for 3 minutes. The platinum electrodes were then checked by comparing the redox potential of quinhydrone solutions of pH 4.00 and 7.00 with previously calculated values appearing in Beckman Instruments Bulletin 99-D.

Fifteen grams of air-dry soil were weighed out in these electrode tubes, flooded with an excess of distilled water, and incubated at 30° C. Redox potential measurements were made within a few minutes after flooding, 12 hours after flooding, and subsequently at daily intervals for 32 days. Only the values obtained a few minutes after submergence and after 30 days are reported. Redox potential measurements were made with a Beckman Zeromatic pH meter using the platinum electrode and a saturated calomel half-cell. Redox potential values were converted into millivolts versus the normal hydrogen electrode.

Extractable Phosphorus

Extractable phosphorus changes in flooded soils were studied in an experiment similar to that used for ammonia accumulation and iron mobilization. Duplicate 5-gram samples were incubated for 30 days at 30° C.

Phosphate was extracted by shaking for 15 minutes on a mechanical shaker with 100 milliliters of 0.1 normal hydrochloric acid and 0.03 normal ammonium fluoride solution. Aliquots of this filtrate were colorimetrically analyzed for phosphorus by the method of Dickman and Bray (*4*).

Results and Discussions

Nitrate Reduction

All of the soils had the capacity to reduce nitrate under submerged conditions (Table 3). Where no organic matter was added, nitrate re-

TABLE 3.—Nitrate Reduction Rates Under Submerged Condition With and Without Added Organic Matter (0.25 Per Cent Ground Corn Leaves)

No.	Soil	Loss of nitrogen in parts per million per day: Flooded, no O.M. added	Flooded, O.M. added	Difference
1	Commerce l	2.31	2.67	+0.36
2	Mhoon sic	4.08	5.17	+1.09
3	Commerce l	1.94	3.51	+1.57
4	Mhoon sicl	2.06	6.57	+4.51
5	Sharkey c	5.49	7.84	+2.35
6	Richland sil	2.67	5.90	+3.23
7	Olivier sil	3.35	6.42	+3.07
8	Lintonia sil	2.93	5.75	+2.82
9	Gallion sil	2.46	3.28	+0.82
10	Yahola sil	1.56	3.29	+1.73
11	Miller sic	3.87	4.15	+0.28
12	Yahola sl	1.94	2.64	+0.70
13	Yahola l	3.10	5.90	+2.80
14	Sharkey cl	2.20	3.13	+0.93
15	Sharkey sl	2.05	3.07	+1.02
16	Sharkey sic	4.71	4.80	+0.09
17	Sharkey l	2.44	3.67	+1.23
18	Crowley sil	0.84	1.81	+0.97
19	Baldwin sicl	4.34	6.32	+1.98
20	Mhoon sicl	3.11	3.04	—0.07
21	Baldwin sicl	3.02	5.90	+2.88
22	Baldwin sicl	2.59	4.47	+1.88
23	Midland sicl	3.10	4.67	+1.57
24	Richland sil	2.24	1.91	—0.33
25	Commerce sl	0.49	0.87	+0.38
26	Iberia c	9.42	9.64	+0.22

duction rates ranged from 0.49 parts per million per day in the Commerce sandy loam (Soil No. 25) to 9.42 parts per million per day in the Iberia clay (Soil No. 26). Nitrate reduction rate was closely related to clay content and organic matter content, with correlation coefficients of 0.820 and 0.596, respectively (Figures 1 and 2).

The addition of 0.25 per cent ground corn leaves increased the nitrate reduction rate in most cases. The change in nitrate reduction rate as a result of the addition of organic matter was by no means consistent, ranging from a decrease of 0.33 parts per million per day in Richland silt loam (Soil No. 24) to an increase of 4.51 parts per million per day in Mhoon silty clay loam (Soil No. 4). The extent to which these soils reacted to the additional energy source was probably determined by the amount of easily decomposable organic matter in the soil as well as the population of denitrifying microorganisms in the soil.

Ammonia Accumulation

The results in Table 4 clearly indicate that flooding brought about large increases in ammonium nitrogen. Where no organic matter was added, the ammonia concentration after submergence ranged from 16.3

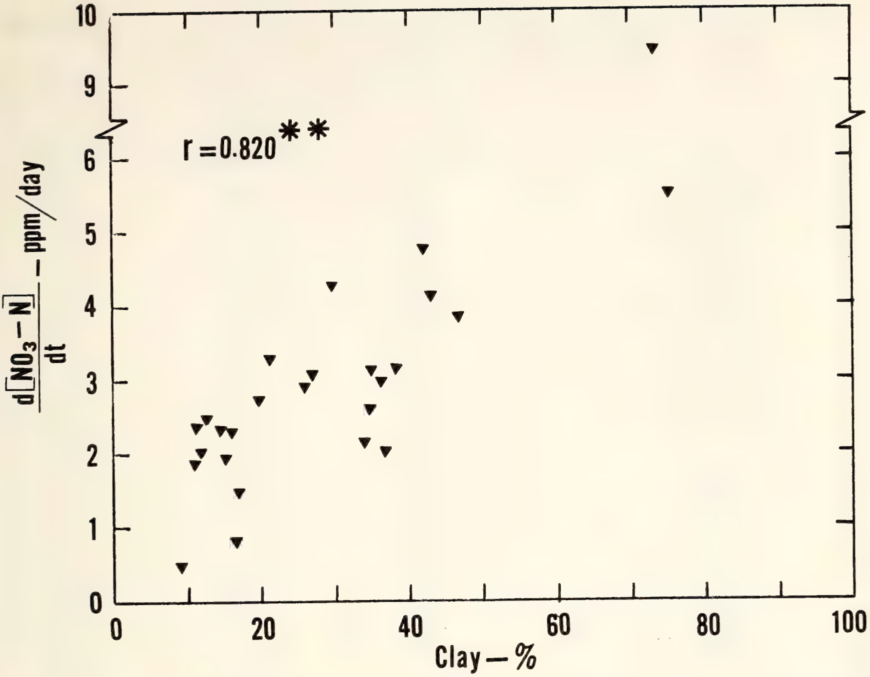

FIGURE 1.–Relation of nitrate reduction rate to clay content.

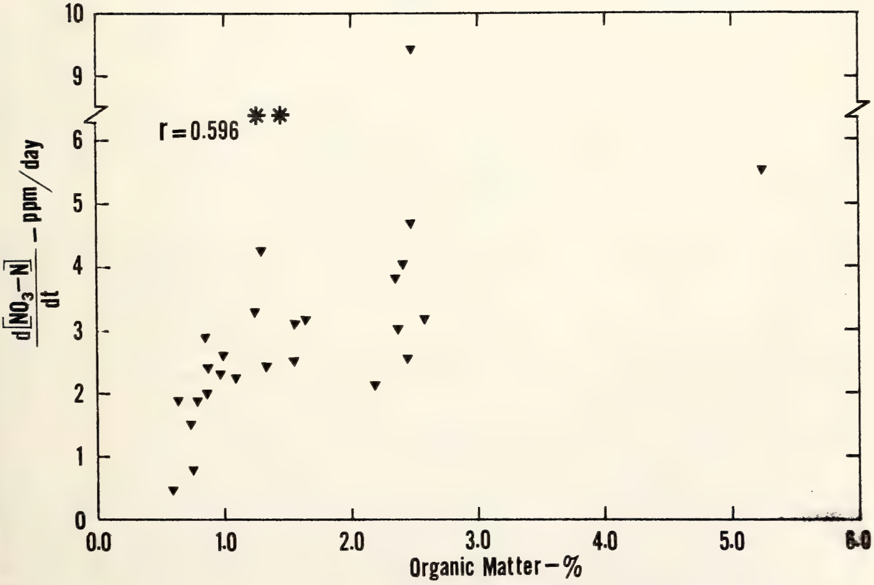

FIGURE 2.–Relation of nitrate reduction rate to organic matter content.

TABLE 4.—Ammonia Production Under Submerged Condition for 30 Days With and Without Added Organic Matter (0.25 Per Cent Ground Corn Leaves)

No.	Soil	Ammonium nitrogen, parts per million Initial	Flooded, no O.M. added	Flooded, O.M. added
1	Commerce l	8.5	44.7	122.2
2	Mhoon sic	12.0	101.7	191.8
3	Commerce l	22.2	44.6	143.2
4	Mhoon sicl	7.3	72.2	133.2
5	Sharkey c	16.7	140.6	142.4
6	Richland sil	13.6	66.4	204.8
7	Olivier sil	13.4	65.3	209.4
8	Lintonia sil	13.7	52.9	135.6
9	Gallion sil	11.0	70.9	125.9
10	Yahola sil	4.8	36.2	95.4
11	Miller sic	9.4	49.3	128.6
12	Yahola sl	7.4	16.3	45.1
13	Yahola l	3.9	34.6	99.0
14	Sharkey cl	5.3	24.0	83.3
15	Sharkey sl	3.6	19.4	78.5
16	Sharkey sic	12.8	72.5	156.8
17	Sharkey l	7.2	40.4	132.4
18	Crowley sil	13.9	50.0	133.8
19	Baldwin sicl	44.2	80.9	244.3
20	Mhoon sicl	8.7	105.9	136.6
21	Baldwin sicl	22.3	92.0	231.8
22	Baldwin sicl	40.3	134.4	171.2
23	Midland sicl	10.2	100.4	149.6
24	Richland sil	14.9	44.1	135.4
25	Commerce sl	15.8	34.3	93.4
26	Iberia c	67.7	109.1	250.7

parts per million in the Yahola sandy loam (Soil No. 12) to 141 parts per million in the Sharkey clay (Soil No. 5). Soils high in organic matter produced larger amounts of ammonia, as is indicated in Figure 3. The amount of nitrogen available from the soil to a lowland rice crop is obviously dependent on the organic matter content.

With the addition of 0.25 per cent ground corn leaves, submergence caused an even greater release of ammonia. The increases of ammonia due to the addition of corn leaves ranged from 1 part per million in the Sharkey clay (Soil No. 5) to 163 parts per million in the Baldwin silty clay loam (Soil No. 19). In some of the soils the added organic matter apparently stimulated the mineralization of nitrogen in excess of that contained in the corn leaves.

Iron and Manganese Mobilization

After submergence for 30 days, almost all of the extractable iron in the soil was present in the ferrous form. For this reason the results reported in Table 5 are for ferrous iron only. Under submerged conditions ferrous iron concentrations varied from 567 parts per million in the Yahola sandy loam (Soil No. 12) to 2,230 parts per million in the

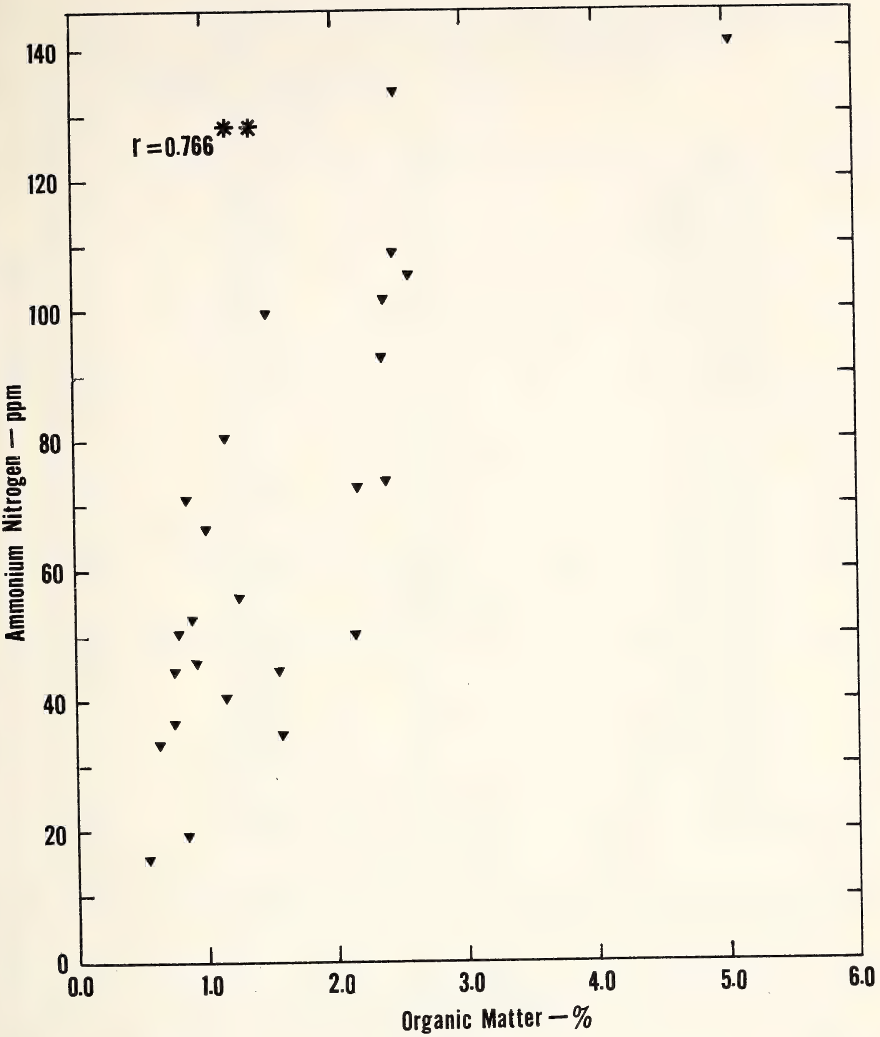

FIGURE 3.—Effect of soil organic matter content on ammonium nitrogen produced after submergence of soil.

Sharkey clay (Soil No. 5). Submergence resulted in a very large release of iron, since the amount of iron extracted from the air-dry soil ranged from 3.3 to 18.7 parts per million (Table 2). Ferrous iron concentration after submergence was positively correlated with clay and organic matter, with r values of 0.625 and 0.674, respectively. The relationship of ferrous iron to soil organic matter content is shown in Figure 4. Organic matter serves as an energy source for the microorganisms that reduce ferric iron to the ferrous form. This reduction may be enzymatic, with ferric iron serving as an electron acceptor in metabolic

TABLE 5.—Extractable Ferrous Iron As Affected by Submergence for 30 Days With and Without Added Organic Matter (0.25 Per Cent Ground Corn Leaves)

No.	Soil	Ferrous iron, parts per million Initial	Flooded, no O.M. added	Flooded, O.M. added
1	Commerce l	6.9	1,350	1,350
2	Mhoon sic	4.4	2,110	2,110
3	Commerce l	2.8	1,630	1,580
4	Mhoon sicl	4.0	2,110	2,110
5	Sharkey c	8.2	2,230	2,240
6	Richland sil	2.6	1,260	1,870
7	Olivier sil	3.2	1,940	2,030
8	Lintonia sil	3.7	1,790	2,000
9	Gallion sil	6.2	1,210	1,220
10	Yahola sil	4.8	661	722
11	Miller sic	3.4	1,990	1,960
12	Yahola sl	2.8	567	661
13	Yahola l	3.7	1,340	1,370
14	Sharkey cl	3.5	1,440	2,000
15	Sharkey sl	3.3	883	1,020
16	Sharkey sic	3.3	2,080	2,070
17	Sharkey l	3.9	1,830	1,910
18	Crowley sil	2.3	1,860	1,930
19	Baldwin sicl	8.2	1,990	2,000
20	Mhoon sicl	4.2	2,080	2,060
21	Baldwin sicl	6.8	2,080	2,050
22	Baldwin sicl	4.7	2,150	2,130
23	Midland sicl	5.2	1,300	1,300
24	Richland sil	2.8	1,910	1,990
25	Commerce sl	5.0	700	700
26	Iberia c	7.4	2,180	2,210

reactions of the organism, or the iron may be reduced chemically by the reduced organic products of microbial decomposition.

Ferrous iron was not increased in all soils by adding 0.25 per cent ground corn leaves to the soils before flooding (Table 5), although many of the soils showed an increase. The effect of added organic matter ranged from an increase of 610 parts per million in the Richland silt loam (Soil No. 6) to a decrease of 50 parts per million in the Commerce loam (Soil No. 3).

Ferrous iron after submergence tended to be higher in soils of low initial pH (Figure 5). A greater release of ferrous iron after submergence can be expected in the more acid soils, since the higher hydrogen ion activity results in more iron being released from crystalline forms and being present in the soil as reducible iron oxide.

Manganese mobilization was markedly increased after flooding the soil, as may be seen in Table 6. The increase ranged from 33.6 parts per million manganese for the Commerce sandy loam (Soil No. 25) to 1,290 parts per million manganese in the Olivier silt loam (Soil No. 7). These increases were due to the reduction of manganic compounds to a more extractable form as a consequence of the anaerobic metabolism

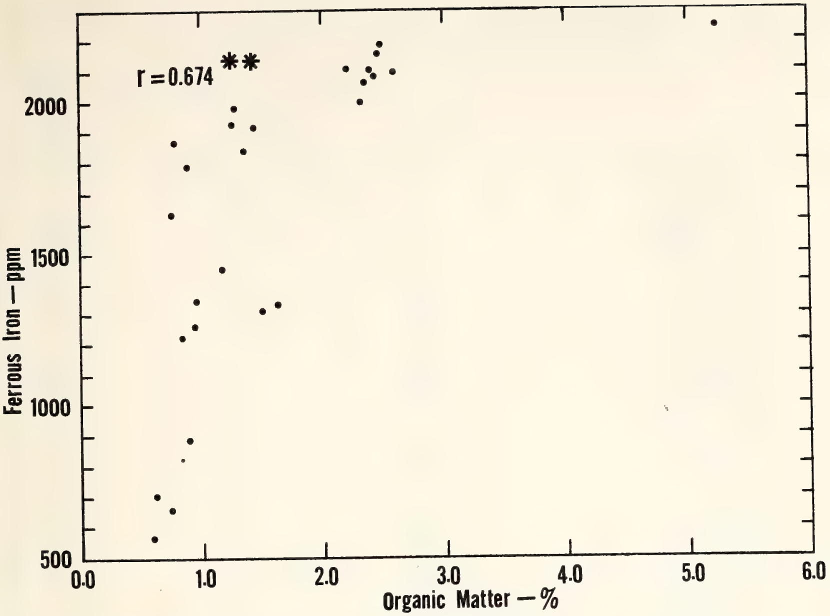

FIGURE 4.—Effect of soil organic matter content on extractable ferrous iron in submerged soils.

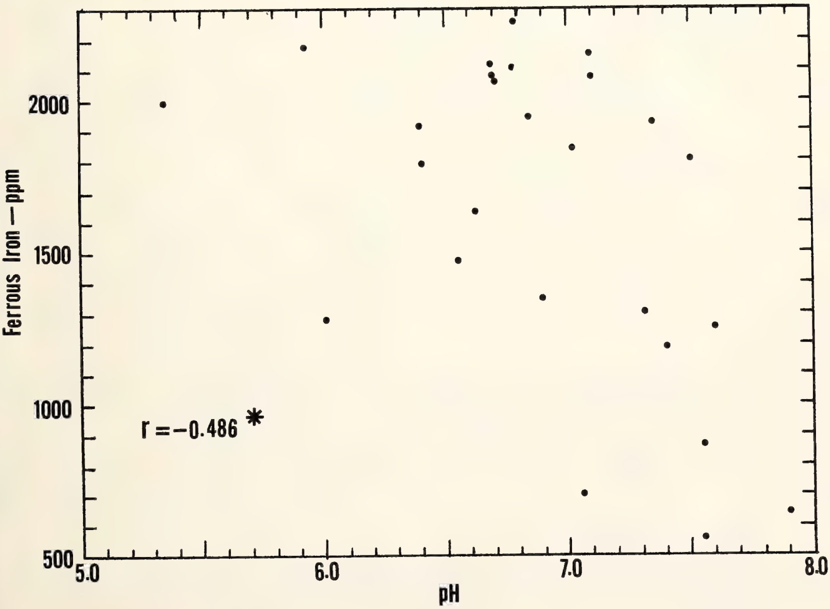

FIGURE 5.—Relation between initial soil pH and ferrous iron extracted from submerged soils.

TABLE 6.—Extractable Manganese As Affected by Submergence for 30 Days With and Without Added Organic Matter (0.25 Per Cent Ground Corn Leaves)

		Manganese, parts per million		
No.	Soil	Initial	Flooded, no O.M. added	Flooded, O.M. added
1	Commerce l	40.1	82	77
2	Mhoon sic	83.8	491	491
3	Commerce l	37.9	116	114
4	Mhoon sicl	74.5	383	408
5	Sharkey c	76.3	441	470
6	Richland sil	159.4	1,400	1,730
7	Olivier sil	88.0	1,380	1,500
8	Lintonia sil	58.1	465	509
9	Gallion sil	16.4	104	103
10	Yahola sil	44.1	89	102
11	Miller sic	59.3	476	474
12	Yahola sl	21.2	85	88
13	Yahola l	57.7	238	243
14	Sharkey cl	49.8	416	463
15	Sharkey sl	20.5	152	153
16	Sharkey sic	75.2	604	616
17	Sharkey l	66.0	220	225
18	Crowley sil	126.6	548	571
19	Baldwin sicl	34.5	159	96
20	Mhoon sicl	129.7	566	578
21	Baldwin sicl	123.8	765	658
22	Baldwin sicl	116.0	612	600
23	Midland sicl	76.2	117	117
24	Richland sil	171.0	767	749
25	Commerce sl	28.1	62	56
26	Iberia c	42.6	223	255

of soil bacteria. Similarly to ferric iron compounds, manganic compounds were reduced to the more soluble manganous form either by serving as biological electron acceptors or by being reduced chemically by organic compounds produced during the anaerobic decomposition of organic matter. According to Mann and Quastel (*6*), both of these processes occur. A striking feature of manganese reduction was that the amount extracted after flooding was closely related to the amount extracted before flooding, as is shown in Figure 6. The regression coefficient shows that there was an approximate six-fold average increase in extractable manganese as a result of submergence. The release of manganese after flooding was considerably higher in the Pleistocene Terrace soils (Richland, Olivier, Lintonia) than in the other soils. Manganese toxicity to cotton and soybeans occurs on the Pleistocene Terrace soils. This toxicity is most pronounced under conditions of poor aeration and low pH.

The effect of added organic matter on the amount of manganese extracted after submergence was inconsistent, ranging from an increase of 330 parts per million in the Richland silt loam (Soil No. 6) to a decrease of 107 parts per million in the Baldwin silty clay (Soil No. 21), Table 6. A probable explanation as to why added organic matter did

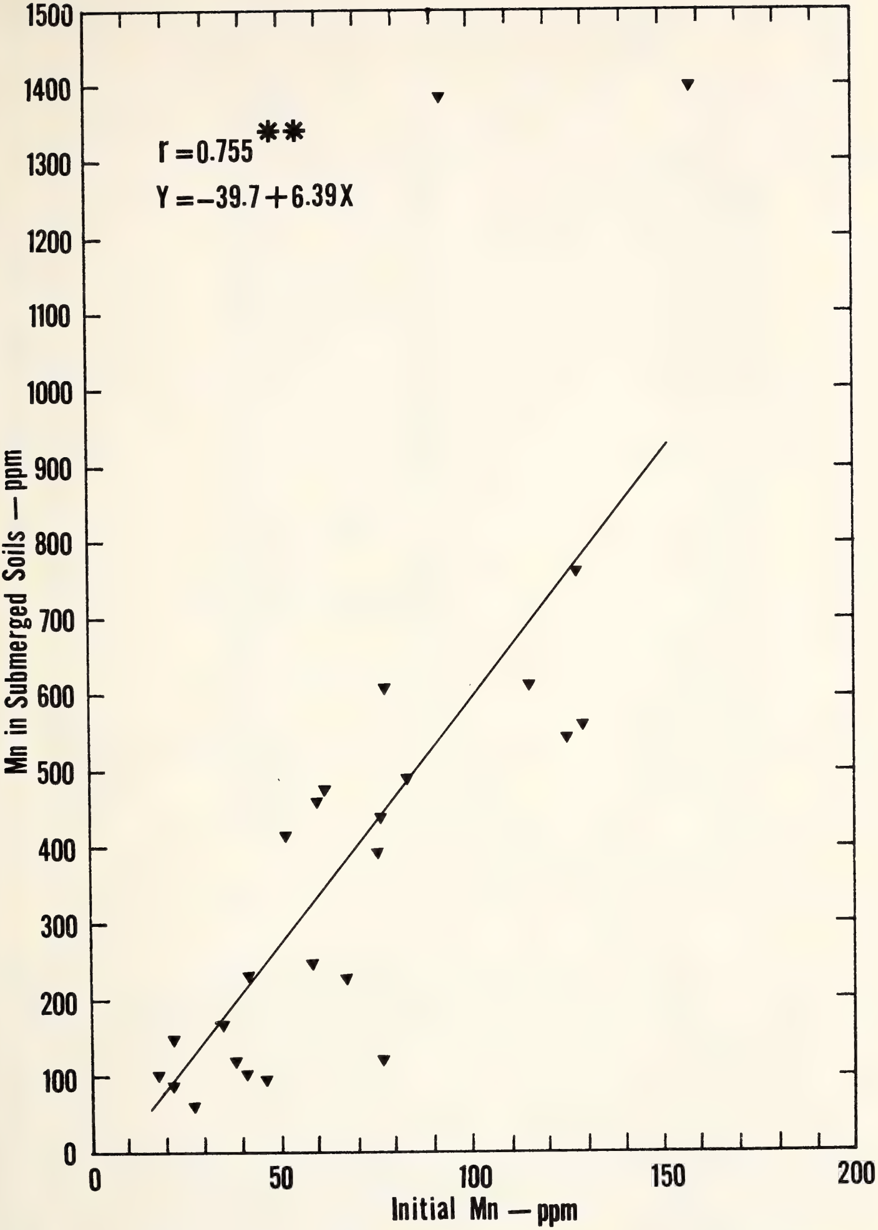

FIGURE 6.—Relation of extractable manganese after submergence to extractable manganese before submergence.

not more definitely increase manganese release may be that manganese is easily reduced under submerged conditions as compared to iron; consequently, additional organic matter was not necessary in order for manganese reduction to proceed readily after submergence.

TABLE 7.—Soil pH As Affected by Submergence for 30 Days With and Without Added Organic Matter (0.25 Per Cent Ground Corn Leaves)

		pH[1]		
No.	Soil	Initial	Flooded, no O.M. added	Flooded, O.M. added
1	Commerce l	6.85	6.90	7.60
2	Mhoon sic	6.45	6.77	7.00
3	Commerce l	6.55	6.62	7.21
4	Mhoon sicl	6.60	6.69	6.99
5	Sharkey c	6.60	6.79	7.03
6	Richland sil	6.00	6.00	7.45
7	Olivier sil	6.15	6.85	7.25
8	Lintonia sil	6.15	6.40	7.20
9	Gallion sil	6.10	7.40	7.49
10	Yahola sil	7.95	7.90	7.23
11	Miller sic	7.65	7.35	7.42
12	Yahola sl	7.90	7.55	7.65
13	Yahola l	7.90	7.60	7.25
14	Sharkey cl	6.95	6.55	7.11
15	Sharkey sl	7.67	7.55	7.48
16	Sharkey sic	6.05	6.70	7.05
17	Sharkey l	6.45	7.02	7.28
18	Crowley sil	6.85	7.50	7.50
19	Baldwin sicl	4.85	5.35	6.50
20	Mhoon sicl	6.70	7.10	7.20
21	Baldwin sicl	5.20	6.69	6.95
22	Baldwin sicl	5.50	7.10	6.99
23	Midland sicl	6.65	7.31	7.06
24	Richland sil	5.65	6.40	7.50
25	Commerce sl	6.50	7.06	7.51
26	Iberia c	5.20	5.94	6.80

[1] One to one ratio of soil to distilled water.

pH

For most of the soils used in this study, soil pH was increased by submergence (Table 7). Flooding increased the pH as much as 1.60 pH units in 30 days for the acid Baldwin silty clay loam (Soil No. 22). The production of hydroxyl ions as a result of the reduction of ferric and manganic compounds and the production of ammonia can account for pH rises of this magnitude in acid soils (*7*). There were certain soils in which flooding produced the reverse effect, namely, a decrease in pH. These decreases occurred for six non-acid soils with original pH values ranging from 6.95 to 7.95. The association between soil pH immediately after submergence and pH 30 days after submergence is illustrated in Figure 7. An analysis of the regression equation shows that, on the average, soils with original pH values above 7.4 decreased in pH after submergence and soils with original pH values below 7.4 increased in pH after submergence. The tendency for soils of low pH to decrease in acidity and for soils of high pH to increase in acidity upon submergence suggests that the pH of a submerged soil tends to be buffered around neutrality by substances produced as a result of submergence. Among

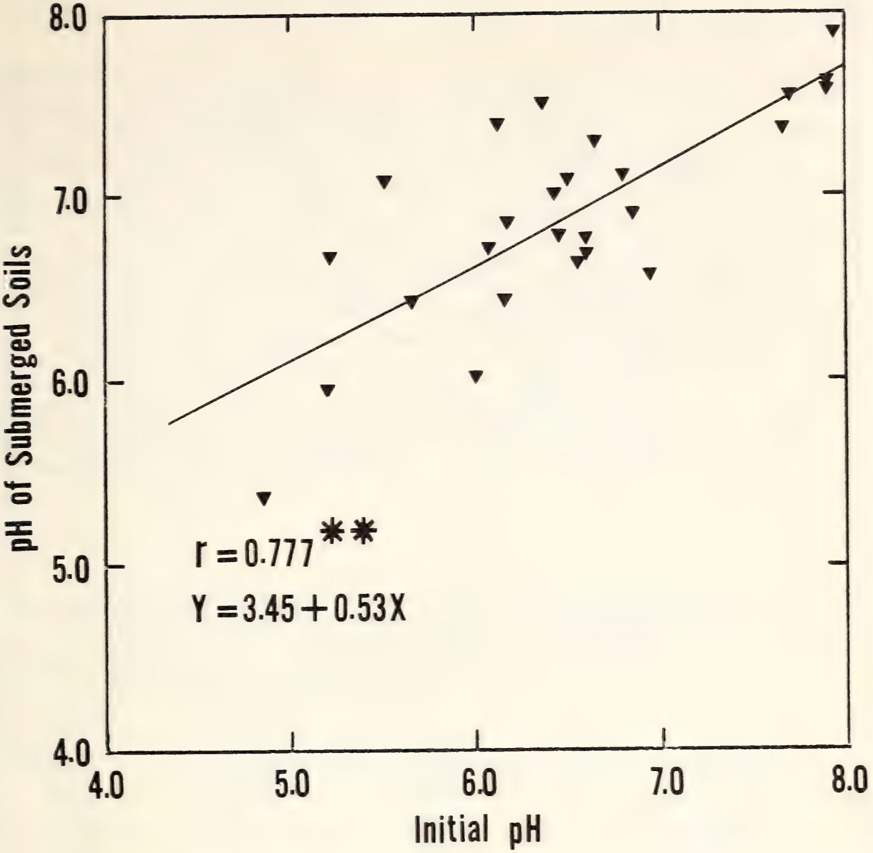

FIGURE 7.—Relation of pH after submergence to pH before submergence.

the compounds that may be active in this respect are ferrous carbonate and ferrous hydroxide. The production of large amounts of ferrous iron during submergence and the sparing solubility of some ferrous salts obviously have an effect on soil pH.

Organic matter favored the development of higher alkalinity in most cases. The increase in pH due to added organic matter was probably the result of an increased release of ammonia, ferrous iron, and manganous manganese. A significant relationship existed between increase in pH and increase in ammonia. The Pleistocene Terrace soils (Richland, Olivier, and Lintonia) exhibited the most pronounced increases in pH from the addition of organic matter. The greatest increases in extractable ammonia, ferrous iron, and manganese as a result of adding organic matter also occurred in these soils.

Continued measurements of pH after 2, 3, and 4 months showed that the large differences which occurred at 1 month as a result of added organic matter disappeared after 3 or 4 months of submergence.

Specific Conductivity

Specific conductivity values of 1/1 soil-water suspensions are shown in Table 8. Submergence for 30 days increased the specific conductivity of all the soils with the exception of the Sharkey silty clay (Soil No. 16) and the Richland silt loam (Soil No. 24). These two soils, which decreased in specific conductivity after submergence, were originally the highest in nitrate nitrogen, and the decrease in conductivity can be explained on the basis of the loss of nitrate through denitrification.

The specific conductivity 30 days after submergence was closely related to the original organic matter content of the soil, as is shown in Figure 8. Adding 0.25 per cent ground corn leaves also increased the specific conductivity. Organic matter served to increase specific conductivity in two ways: by the production of ionizable reduced organic materials from the decomposition of organic matter, and by serving as an energy source for the reduction of inorganic compounds to more soluble forms.

TABLE 8.—Soil Specific Conductivity As Affected by Submergence for 30 Days With and Without Added Organic Matter (0.25 Per Cent Ground Corn Leaves)

		Specific conductivity – mmhos per cm.[1]		
No.	Soil	Initial	Flooded, no O.M. added	Flooded, O.M. added
1	Commerce l	0.190	0.200	0.693
2	Mhoon sic	0.340	0.965	1.802
3	Commerce l	0.150	0.208	0.901
4	Mhoon sicl	0.392	0.772	1.081
5	Sharkey c	0.772	1.351	1.802
6	Richland sil	0.130	0.284	0.540
7	Olivier sil	0.170	0.416	0.772
8	Lintonia sil	0.125	0.186	0.676
9	Gallion sil	0.136	0.318	0.601
10	Yahola sil	0.270	0.386	0.901
11	Miller sic	0.450	0.845	1.081
12	Yahola sl	0.229	0.318	0.676
13	Yahola l	0.351	0.540	1.081
14	Sharkey cl	0.294	0.416	1.502
15	Sharkey sl	0.211	0.284	0.711
16	Sharkey sic	0.872	0.676	1.351
17	Sharkey l	0.273	0.416	0.901
18	Crowley sil	0.257	0.416	0.711
19	Baldwin sicl	0.284	0.540	0.772
20	Mhoon sicl	0.520	0.901	1.228
21	Baldwin sicl	0.520	0.901	1.228
22	Baldwin sicl	0.375	0.901	1.351
23	Midland sicl	0.300	0.540	0.901
24	Richland sil	0.397	0.300	1.081
25	Commerce sl	0.222	0.225	0.772
26	Iberia c	0.552	1.081	1.502

[1] One to one ratio of soil to distilled water.

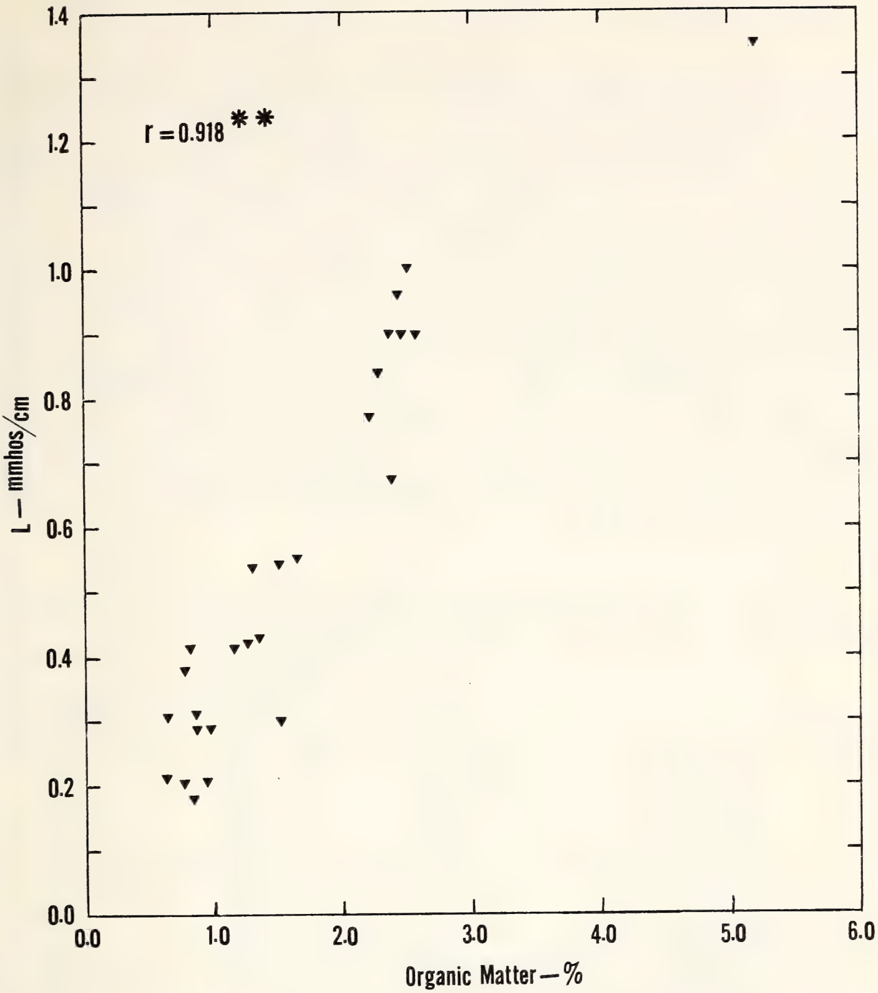

FIGURE 8.—Effect of organic matter content on specific conductivity of submerged soils.

Redox Potential

The redox potential (Eh) values of the soils before and after 30 days of submergence are shown in Table 9. Determinations made immediately after submergence showed the redox potentials of the soils to range from 424 millivolts in the Yahola sandy loam (Soil No. 12) to 634 millivolts in two Baldwin silty clay loam soils (Soils No. 19 and No. 21). There was a close relationship between the redox potential taken a few minutes after submergence and the initial pH of the soil. This relationship is illustrated in Figure 9. The Eh/pH slope was —61.8 millivolts per pH unit. This is very close to the theoretical value of —60 millivolts per pH unit for the oxygen system. These results for freshly wetted soils agree with those reported by workers at the International Rice Research Institute *(2)*. Most of the variation in original redox potential under well-aerated conditions was obviously due to differences in pH. Correcting these initial redox potential values to pH 7.0 by means of the regression equation shown in Figure 9 gives an initial redox potential for freshly wetted soils of 503 millivolts.

TABLE 9.—Soil Eh As Affected by Submergence for 30 Days With and Without Added Organic Matter (0.25 Per Cent Ground Corn Leaves)

		Eh – millivolts		
No.	Soil	Initial[1]	Flooded, no O.M. added	Flooded, O.M. added
1	Commerce l	+519	—238	—238
2	Mhoon sic	+562	—234	—254
3	Commerce l	+554	—236	—234
4	Mhoon sicl	+474	—205	—241
5	Sharkey c	+444	—241	—246
6	Richland sil	+601	—239	—251
7	Olivier sil	+546	—238	—256
8	Lintonia sil	+589	—216	—234
9	Gallion sil	+569	—226	—228
10	Yahola sil	+461	—288	—251
11	Miller sic	+476	—236	—284
12	Yahola sl	+424	—294	—291
13	Yahola l	+444	—281	—276
14	Sharkey cl	+492	— 94	—244
15	Sharkey sl	+477	—258	—268
16	Sharkey sic	+592	—244	—246
17	Sharkey l	+582	—226	—254
18	Crowley sil	+516	—284	—266
19	Baldwin sicl	+634	—206	—223
20	Mhoon sicl	+491	—251	—254
21	Baldwin sicl	+634	—246	—253
22	Baldwin sicl	+579	—251	—246
23	Midland sicl	+566	—244	—244
24	Richland sil	+582	—236	—244
25	Commerce sl	+494	—254	—258
26	Iberia c	+579	—216	—234

[1] Measured immediately after flooding.

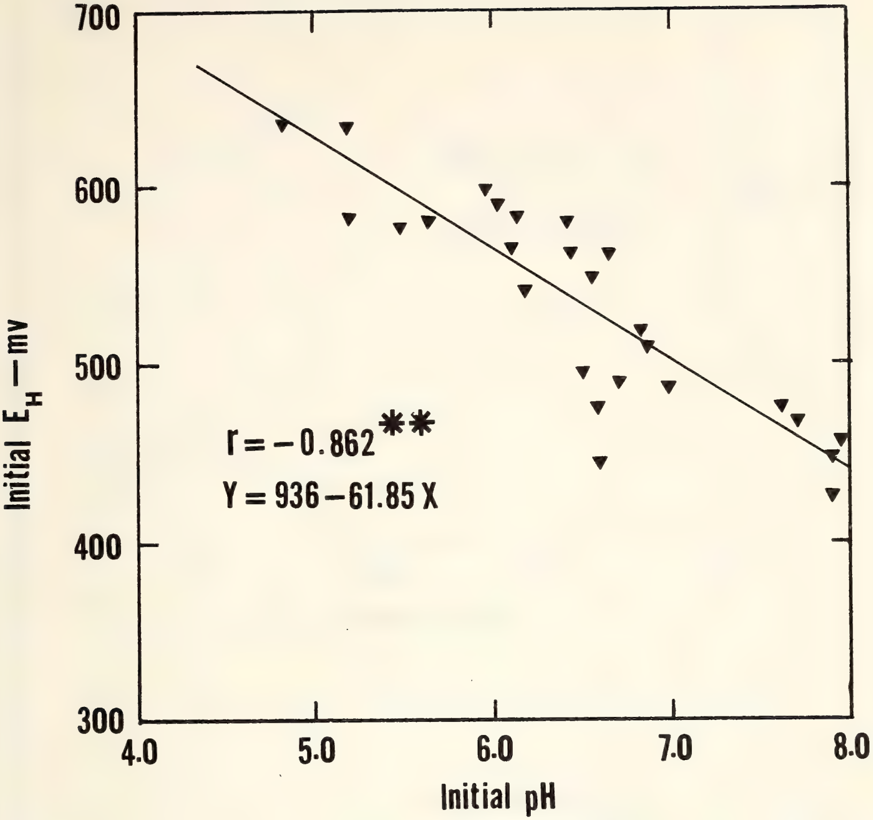

FIGURE 9.—Relation of redox potential to pH before submergence.

As expected, redox potential after 30 days submergence indicated highly reduced conditions. All of the soils except Sharkey clay loam (Soil No. 14) had redox potentials below —200 millivolts. Added organic matter had little effect in further reducing the potential except for the above mentioned soil. The low organic matter content of this soil evidently accounted for its relatively high redox potential after submergence.

The soil redox potential 30 days after submergence was also pH dependent (Figure 10). An Eh/pH slope of —36 millivolts per pH unit was obtained. This is a considerably different slope than that which existed immediately after submergence of the soils. Redox systems other than the oxygen system were obviously functioning in these highly reduced soils.

The ability of the inorganic iron and manganese systems to buffer the redox potential was studied. Manganese and iron have been credited with the capacity to buffer the redox potential of the soil: manganese in the range 100 to —50 millivolts and iron in the range —50 to

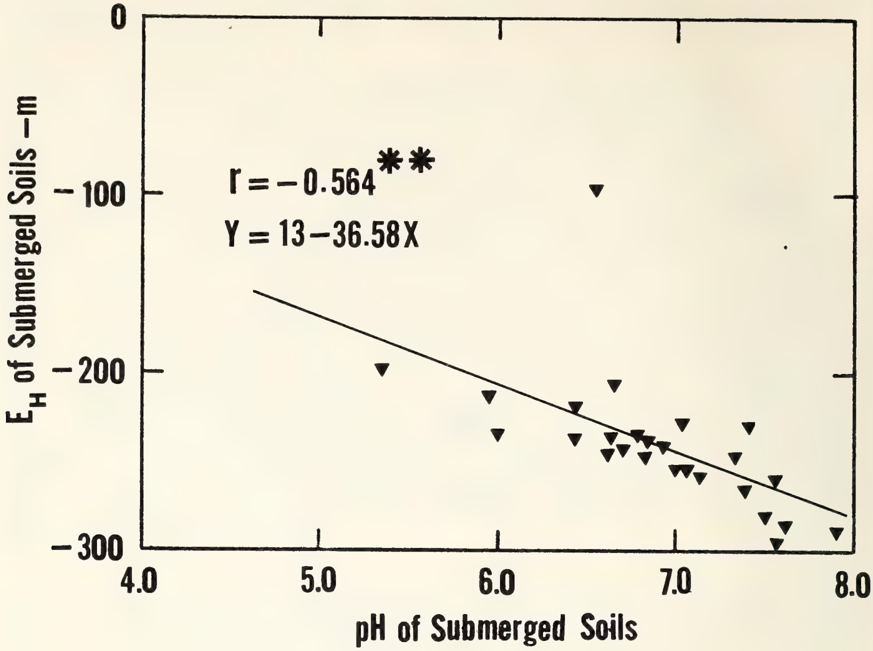

FIGURE 10.—Relation of redox potential to pH after submergence.

—200 millivolts (*2*). In this study iron proved to be effective in slowing the fall of redox potential after submergence. The higher the amount of reducible ferric iron, the greater the buffering effect, as measured by the time required for the potential to fall to —200 millivolts (Figure 11). No statistically significant relationship was established between the number of days required for the redox potential to fall to —100 millivolts and the amount of manganese released. The ferric-ferrous system appears to be one of the dominant redox systems in soils insofar as retarding the establishment of reducing conditions is concerned. The ability of ferric iron to retard the redox potential fall is apparently due in part to the large amount of reducible ferric iron present in most soils.

Because of its oxidizing ability, nitrate nitrogen should also serve to retard the decrease in redox potential in a submerged soil. In the soils studied no association was observed between the initial nitrate content of the soils and the rate of decrease of redox potential. This may have been due to the low nitrate content of most of the soils. A separate study was made to determine what effect nitrate had on stabilizing the redox potential of the soil. Samples of a Crowley silt loam were submerged for 23 days and then received various rates of nitrate nitrogen. The results of this experiment are shown in Figure 12. The potential of all of the samples increased after nitrate was added. The sample which received no nitrate showed a temporary potential rise due to the oxygen

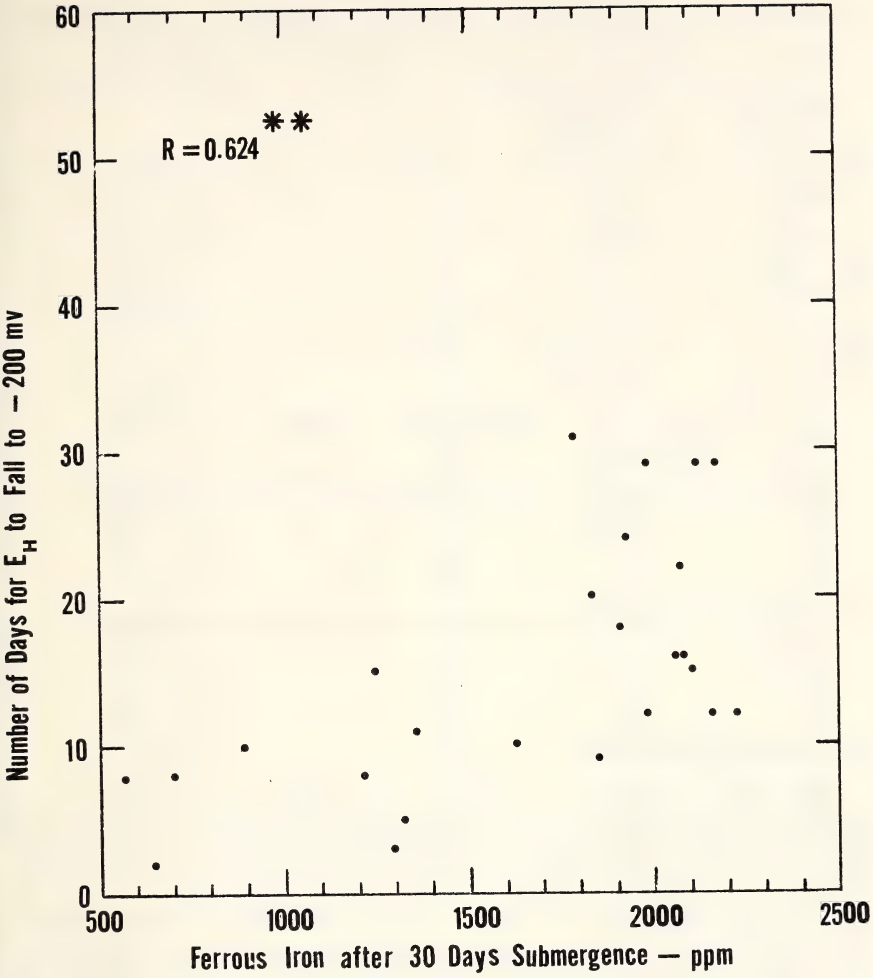

FIGURE 11.—Relation of amount of extractable ferrous iron after submergence to time required for redox potential to decrease to −200 millivolts.

mixed in the soil when all samples were stirred at the time nitrate was added. The elevation of redox potential persisted until all of the nitrate was reduced. This required 11 days and 24 days for the samples receiving 50 and 200 parts per million, respectively. The potential of the soil receiving nitrate nitrogen at the rate of 1,200 parts per million had not fallen to its original highly reduced value after 72 days.

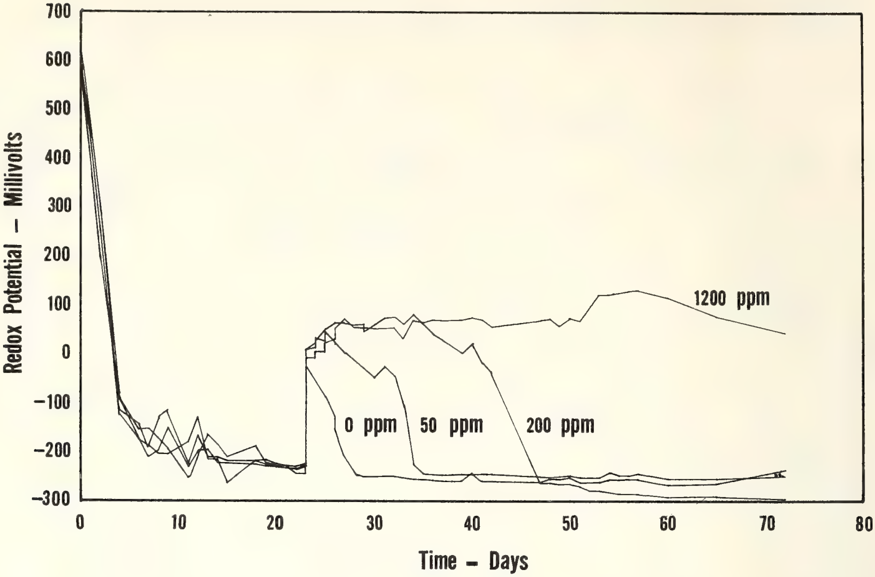

FIGURE 12.—Effect of added nitrate on redox potential of submerged soil.

Extractable Phosphorus

Most soils showed an increase in extractable phosphorus after submergence. The effect of flooding ranged from an increase of 393 parts per million in the Sharkey clay (Soil No. 5) to a decrease of 30 parts per million in the Sharkey loam (Soil No. 17) (Table 10). There was a close relationship between the amount of phosphorus extracted before submergence and the amount extracted after submergence (Figure 13). The regression equation showed that there was an average increase of 21 per cent in extractable phosphorus due to submergence. The increase in extractable phosphorus as a result of submergence is important in the phosphorus nutrition of lowland rice and probably accounts for the smaller response rice makes to added phosphate as compared to upland crops. A highly significant correlation existed between phosphorus after flooding and soil organic matter content.

An interesting relationship existed between changes in extractable phosphorus and changes in extractable ferrous iron as a result of submergence (Figure 14). Increases in extractable phosphorus occurred only in those soils that released large amounts of iron. There was no appreciable increase in extractable phosphorus after submergence in soils that released less than about 1,800 parts per million iron. An increase in the release of iron beyond this point resulted in a marked release of phosphate.

The phosphate released as a result of submergence was largely re-

TABLE 10.—Extractable Phosphorus As Affected by Submergence for 30 Days With and Without Added Organic Matter (0.25 Per Cent Ground Corn Leaves)

		Phosphorus, parts per million		
No.	Soil	Initial	Flooded, no O.M. added	Flooded, O.M. added
1	Commerce l	438	439	418
2	Mhoon sic	375	533	550
3	Commerce l	348	324	320
4	Mhoon sicl	409	511	525
5	Sharkey c	421	818	819
6	Richland sil	106	166	193
7	Olivier sil	195	317	359
8	Lintonia sil	96	126	167
9	Gallion sil	148	152	155
10	Yahola sil	312	283	283
11	Miller sic	345	386	387
12	Yahola sl	263	247	249
13	Yahola l	328	348	216
14	Sharkey cl	321	319	344
15	Sharkey sl	344	344	334
16	Sharkey sic	246	348	348
17	Sharkey l	378	348	366
18	Crowley sil	6	12	17
19	Baldwin sicl	53	91	100
20	Mhoon sicl	770	995	1,050
21	Baldwin sicl	382	635	639
22	Baldwin sicl	267	440	451
23	Midland sicl	46	55	76
24	Richland sil	42	88	118
25	Commerce sl	394	395	386
26	Iberia c	75	179	201

ductant soluble and "occluded" phosphate (*3*), or phosphate coprecipitated with ferric oxide. This phosphate was extractable only after the ferric oxide had been reduced to the more soluble ferrous form. The greatest percentage increase in phosphate release as a result of submergence occurred in several of the more poorly drained soils. The better-drained Recent alluvial soils (Commerce and Yahola) did not release phosphate as a result of submergence.

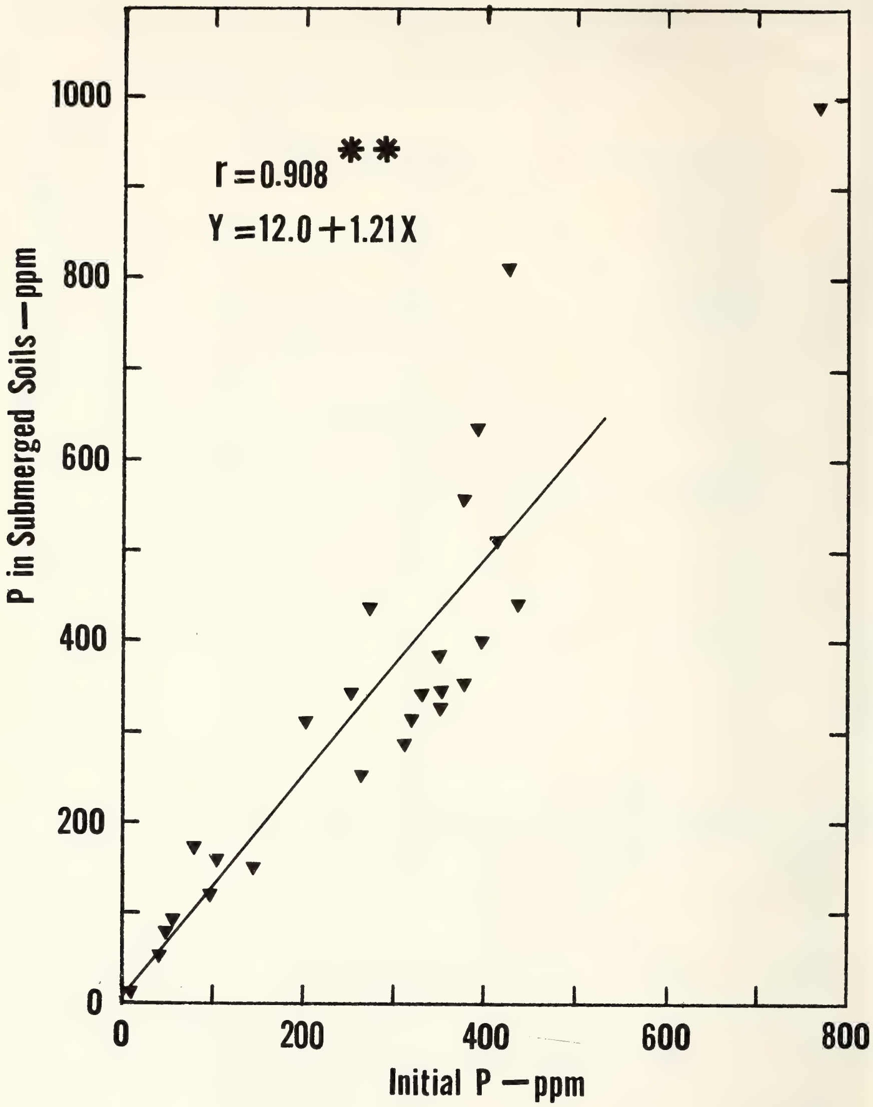

FIGURE 13.—Relation between extractable phosphate before submergence and extractable phosphate after submergence.

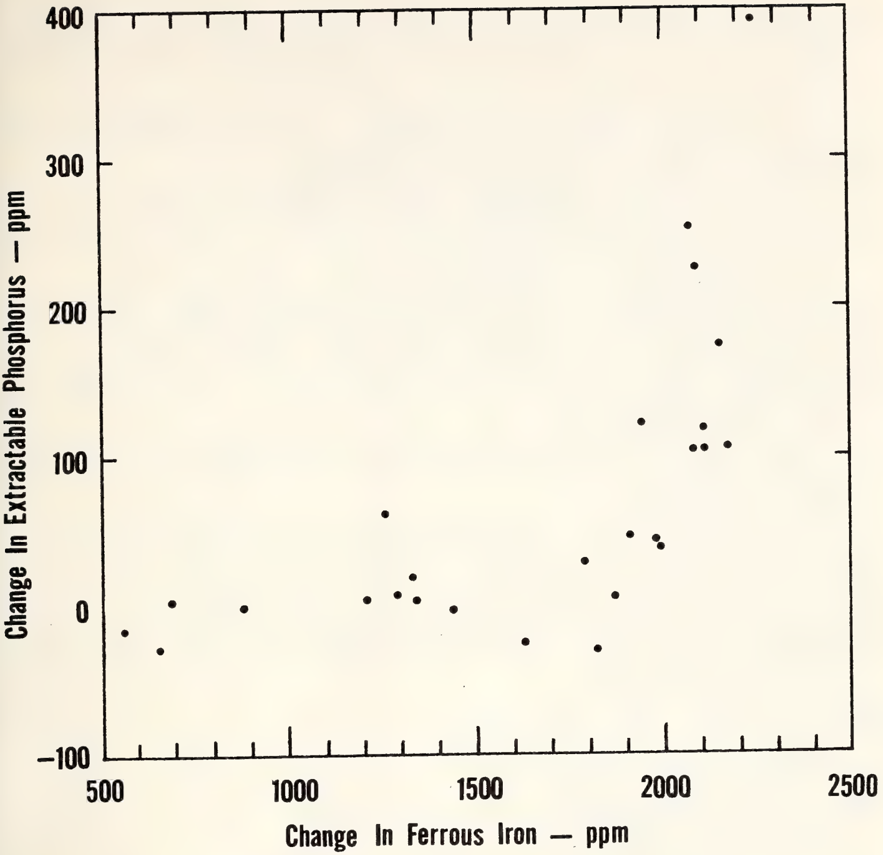

FIGURE 14.—Relation of the increase in extractable phosphorus resulting from submergence to the increase in extractable ferrous iron.

Summary

A study was made of the effects of submergence on several biological and physicochemical properties of 26 Louisiana soils.

All soils reduced nitrate nitrogen under submerged conditions. Nitrate reduction rate was positively correlated with soil organic matter and clay. Added organic matter generally increased the nitrate reduction rate.

Flooding the soil resulted in large increases in ammonia content. The addition of 0.25 per cent corn leaves further increased the production of ammonia.

Large quantities of iron were released in the ferrous form as a result of submergence. Additional organic matter usually increased the release of iron.

Approximately six times as much manganese was extracted from the soil after 30 days submergence as under air-dry conditions. Manganese release under anaerobic conditions was especially high in the Pleistocene Terrace soils.

Submergence tended to shift the soil pH to values near the neutral point. In general, acid soils increased in pH after submergence and alkaline soils decreased in pH after submergence.

Specific conductivity generally increased upon submerging the soil. Decreases in specific conductivity after submergence occurred only for soils initially high in nitrate nitrogen.

As expected, redox potentials decreased from high values immediately after flooding to very low values after 30 days. Both initially and after 30 days, the redox potential was closely related to soil pH. Iron compounds in the soil were active in retarding the decline of redox potential after submergence.

The potential of a highly reduced soil was increased by the addition of nitrate. The potential did not fall to its previous value until all of the nitrate was reduced.

Extractable phosphorus was about 21 per cent higher under reduced conditions brought on by submergence. The increase in phosphate release as a result of submergence appeared to be related to the reduction of ferric compounds to the more extractable ferrous forms. Appreciable phosphate release occurred only in those soils that released large amounts of ferrous iron.

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GROWTH PATTERNS AND SURVIVAL TENDENCIES OF FIRMS IN THE LOUISIANA DAIRY INDUSTRY

W. H. Alexander
and
D. C. Williams

PARTMENT OF AGRICULTURAL ECONOMICS
AND AGRIBUSINESS
Louisiana State University and
Agricultural and Mechanical College
Agricultural Experiment Station
Doyle Chambers, Director

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Foreword

Changes in the number and size distribution of fluid milk producing and processing firms have taken place in Louisiana during the last decade. Firms in both segments of the industry have become fewer in number but larger in size. This report considers patterns of growth and scale of operation of dairy firms as they relate to survival. Projections are made of the number and size distribution of such firms in future time periods.

Acknowledgments

Acknowledgments are gratefully extended to the Market Administrators of New Orleans and the Northern Louisiana Federal Order Milk Markets and to the Division of Milk Testing of the Louisiana Department of Agriculture and Immigration for providing valuable statistics and information.

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Growth Patterns and Survival Tendencies Of Firms in the Louisiana Dairy Industry

WILLIAM H. ALEXANDER AND D. C. WILLIAMS, JR.

Technological changes in the production and processing of milk have resulted in changes in number and size of firms in the Louisiana dairy industry. The rate and patterns of growth have not been the same for all sizes of firms. Since changes do not come about in accordance with fixed proportions, they have implications for chances of survival by individual firms.

Market statistics for the industry during the last decade reflect changes in the demand for output of dairy firms. Variations in market shares by individual firms have been reflected by a change in number and size distribution of firms in the industry. The trend has been toward fewer and larger milk producing units as well as processing and distributing firms. These data are useful as market information but must be interpreted if they are to be useful as management guides for firms of varying sizes. The fact that changes are inevitable leads to problems in the formulation of goals for the future survival and scale of operation of firms in the dairy industry.

The purpose of this analysis is to describe and analyze the structural changes which have taken place among firms operating in fluid milk markets in Louisiana. Prospective growth patterns and size distribution of surviving firms in future time periods are estimated in this analysis. An index of firm mobility among size categories was determined for both segments (producers and processors) of the dairy industry.

The analytical tool used in the study is one which consists of observing the growth or movements of individual firms among specific size categories over given time periods. From these observations and measurements it is possible to derive a quantitative estimate of the growth pattern which firms are likely to take in the future. Changes, similar to those experienced in the past, for firms in the industry are expected to persist in future time periods. This analysis should be most helpful to firms for long-range planning of future operations.

Data for the study were obtained from milk market administrators of state and federal marketing orders, producer associations, and experiment station publications. The data include statistics for fluid milk marketed by both producers and handlers in the state.

For analytical purposes, Louisiana was divided into three milk market areas: New Orleans, Northern, and Central (Figure 1).

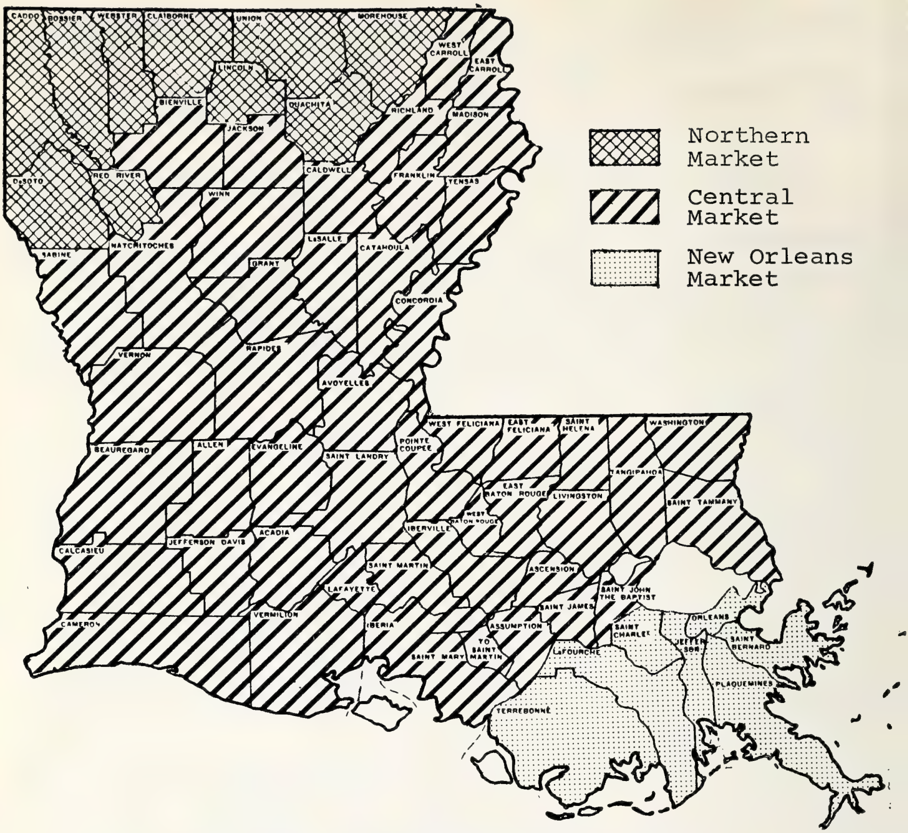

FIGURE 1.—Milk Marketing Areas of Louisiana.

Units for Measuring Size of Firms

Handlers

The primary market for milk in Louisiana is for fluid use, i.e., sales in packaged form. Thus, for this analysis, retail sales of fluid milk were used as the measure of size for milk handling firms. Statistical tests indicated that the volume of fluid milk handled during a single month, January, properly reflected the size of firms for each of the respective years. Results would not have been significantly different if total annual data had been used. Since these data were readily available on a monthly basis, a single month, January, each year was used to reflect firm size.

Producers

Established daily base, in terms of pounds of milk, was used as the measure of size for producers. The established daily base of a producer is the average volume of milk delivered by such producer during a base-forming period. The base formed during such a period was used to determine each producer's share of Class I sales during the base operating period.

This study does not include data for the "producer-handler" type of dairy firms. A producer-handler is a person who is both a dairy farmer and a milk processor. He does not purchase milk from dairy farmers but processes and sells only his own production. There are only nine such firms in the state and they account for less than one per cent of total milk sales.

Changes in Size of Fluid Milk Firms

In general, the number of dairy firms has been decreasing and the average size of the firms remaining has been increasing in Louisiana since 1950. The average annual volume of milk sales by handlers in 1951 was 6.1 million pounds. By 1961, average sales per handler had doubled to 13.5 million pounds (Table 1).

During January 1962 the three largest milk handling firms in Louisiana accounted for 40 per cent of the total packaged fluid milk sales in the state. The six largest handlers accounted for slightly more than half of the total fluid milk sales. Fifteen handlers accounted for more than 75 per cent of the sales. This means that 25 per cent of the total packaged milk was sold by 53 handlers, or 78 per cent of the handlers in Louisiana.

Changes of Milk Handling Firms Among Size Categories

Changes of firms from one size category to another were tabulated for specific time periods. Such changes were analyzed and used to estimate future patterns of growth and scales of operation among firms.

Data showing changes in size of milk handling firms in the New Orleans Market were only available for the period 1958 through 1962. Data for the Northern and Central Markets were available for the period 1956 through 1962. With these data it was possible to observe four movements of each milk handling firm among size categories in the New Orleans Market and six movements of each firm in the other markets.

Volumes of milk sales per month, as shown in Table 2, were used to represent firm size. Since some firms went out of business during the period of study it was necessary (for analytical purposes) to provide a size category of "no production" (category I).

Observations of year to year changes in size were tabulated and serve to indicate the movement of firms among size categories. The size cate-

TABLE 1.—Number and Size of Milk Handlers, Number of Producer-Handlers and Milk Cooling Stations, Louisiana Milk Markets, 1951-1962

Year	New Orleans			Northern Louisiana*		
	Handlers		Producer-handlers	Handlers		Producer-handlers
	Average number	Average sales per handler***		Average number	Average sales per handler***	
	Per month	*Mil. lbs. per year*	*Number*	*Per month*	*Mil. lbs. per year*	*Number*
1951	25	9.9	NA	17	6.6	NA
1952	26	10.1	NA	16	7.3	NA
1953	25	11.2	8	15	8.4	3
1954	26	11.6	NA	15	8.8	NA
1955	29	10.9	NA	15	9.3	NA
1956	28	12.5	NA	16	9.7	NA
1957	27	13.1	4	15	11.7	4
1958	33	11.2	NA	13	13.5	NA
1959	32	11.9	5	13	13.5	3
1960	32	13.0	NA	13	14.7	NA
1961	32	14.4	NA	13	13.9	NA
1962	32	13.6	1	12	14.9	2

(Continued)

TABLE 1.—(Continued)

Year	Central**			Three Markets Combined			
	Handlers		Producer-handlers	Handlers		Producer-handlers	Cooling stations
	Average number	Average sales per handler***		Average number	Average sales per handler***		
	Per month	*Mil. lbs. per year*	*Number*	*Per month*	*Mil. lbs. per year*	*Number*	*Number*
1951	44	3.8	NA	86	6.1	NA	NA
1952	41	4.6	NA	83	6.7	NA	NA
1953	37	5.4	24	77	7.8	35	13
1954	37	6.1	NA	78	8.3	NA	NA
1955	39	6.1	NA	83	8.2	NA	NA
1956	39	6.6	NA	83	9.0	NA	NA
1957	39	8.6	12	81	10.3	20	13
1958	34	9.1	NA	80	10.5	NA	NA
1959	29	10.0	17	76	11.0	25	11
1960	28	10.8	NA	73	12.3	NA	NA
1961	28	13.2	NA	73	13.5	NA	NA
1962	27	11.6	6	71	12.9	9	9

*Prior to August 1958, data for Northwest and Northeast Louisiana were reported as two separate markets. These markets were combined into a single area in August 1958 and called the Northern Louisiana Marketing Area.

**Data as reported for the Central, Southwest, and Southeast Areas were combined to represent the Central Louisiana Market.

***Computed by dividing the average number of handlers per month into total sales in the market for the year.

NA—Not Available.

Source: *Louisiana Annual Milk Marketing Reports,* and *Milk Processing Plants in Louisiana,* Louisiana Department of Agriculture and Immigration, Division of Milk Testing, 1953, 1957, 1959, and 1962.

TABLE 2.—Ranges of Unequal Size Category Limits Used in the Analysis of Growth Patterns of Fluid Milk Firms

Size category	Category limits
	Thousand pounds per month
I	0
II	1 - 100
III	101 - 250
IV	251 - 400
V	401 - 750
VI	751 - 3,000
VII	Over 3,000

gories for recording the movement of firms among size groups are shown on the top and along the side of Tables 3 and 4. Movements of firms among size categories for all markets are shown in Table 3. The numbers in Table 3 represent the total number of firms that moved from one size category to another during all time periods. For example, observe the second row in the table for the New Orleans Market. There were two firms that moved from category II to category I, or discontinued operation. In the year prior to exit they were selling less than 101 thousand pounds of milk per month.

The chances of exit by a firm or changing in size are shown in Table 4. According to the experience of packaged fluid milk sales by handlers in the New Orleans Market a firm selling between 1,000 and 100,000 pounds of milk per month (second row, column 2), will remain in the same size category the following year 92.3 times out of 100. The probability of exit of firms of this size in one year was .051, and probability of increasing sales within the range of size category III was .026. The remainder of the table is interpreted in a similar fashion.

The underlined figures on the main diagonal in Table 4 indicate the chances of firms' remaining in the same size category at the end of each time period. There is a strong tendency for firms to remain within a given size category from one year to the next. Naturally, if the size categories were smaller or if the time periods were longer, the number of moves among size categories would be larger. The probability of a change in the size of a firm as well as the direction of change can be derived from Table 4. For example, there is a probability of .278 that firms selling between 1 and 100 thousand pounds of milk per month in Central Louisiana Marketing Area will decrease in size; and a probability of .083 that they will increase in size (second row under Central Louisiana Market heading). In other words, the probability that firms of that size will decrease in size is greater than the probability for an increase. However, for firms that sell between 101 and 250 thousand pounds of milk per month, the probability of an increase in size, .152

TABLE 3.—Movements of Milk Handlers Among Size Categories, as Reflected by Packaged Fluid Milk Sales, Louisiana Markets, 1956 through 1962

Size category in given year	Size category in following year						
	I	II	III	IV	V	VI	VII
	(Thousand pounds per month)						
	0	1-100	101-250	251-400	401-750	751-3,000	Over 3,000
(Thous. lbs. per month)	— — — — — *Number of firms* — — — — —						
	NEW ORLEANS MARKET*						
I (0)	10	1	–	–	1	1	–
II (1 – 100)	2	36	1	–	–	–	–
III (101 – 250)	1	1	15	1	–	–	–
IV (251 – 400)	–	–	1	15	2	–	–
V (401 – 750)	–	–	–	1	14	–	–
VI (751 – 3,000)	–	–	–	–	–	13	–
VII (Over 3,000)	–	–	–	–	–	–	12
	NORTHERN MARKET						
I (0)	20	3	–	–	–	–	–
II (1 – 100)	3	1	3	–	1	–	–
III (101 – 250)	1	1	13	5	–	–	–
IV (251 – 400)	1	–	3	7	2	–	–
V (401 – 750)	–	–	1	–	9	1	–
VI (751 – 3,000)	–	–	–	–	–	17	–
VII (Over 3,000)	–	–	–	–	–	1	8
	CENTRAL MARKET						
I (0)	48	3	1	–	–	1	–
II (1 – 100)	10	23	3	–	–	–	–
III (101 – 250)	2	7	41	8	1	–	–
IV (251 – 400)	2	–	4	10	5	–	–
V (401 – 750)	–	–	–	3	30	1	–
VI (751 – 3,000)	1	–	–	–	1	35	–
VII (Over 3,000)	–	–	–	–	–	–	–
	THREE MARKETS COMBINED						
I (0)	78	7	1	–	1	2	–
II (1 – 100)	15	60	7	–	1	–	–
III (101 – 250)	4	9	69	14	1	–	–
IV (251 – 400)	3	–	8	32	9	–	–
V (401 – 750)	–	–	1	4	53	2	–
VI (751 – 3,000)	1	–	–	–	1	59	1
VII (Over 3,000)	–	–	–	–	–	1	26

*Data on movements of firms among size categories were available for the New Orleans Market only from 1958 through 1962. In the other markets it was available from 1956 through 1962.

Source: Offices of the Milk Marketing Administrators, New Orleans, Shreveport, and Baton Rouge, Louisiana.

TABLE 4.—The Probability of Fluid Milk Firms Expanding, Remaining Stationary, or Contracting in any Given Year, as Reflected by Packaged Fluid Milk Sales, Louisiana Markets

Size category in given year	Size category in following year						
	I	II	III	IV	V	VI	VII
	(Thousand pounds per month)						
	0	1-100	101-250	251-400	401-750	751-3,000	Over 3,000
(Thous. lbs. per month)	— — — — *Chances of movement — percentages* — — — —						
NEW ORLEANS MARKET							
I (0)	.997	.001	–	–	.001	.001	–
II (1 - 100)	.051	.923	.026	–	–	–	–
III (101 - 250)	.056	.056	.832	.056	–	–	–
IV (251 - 400)	–	–	.056	.833	.111	–	–
V (401 - 750)	–	–	–	.067	.933	–	–
VI (751 - 3,000)	–	–	–	–	–	1.000	–
VII (Over 3,000)	–	–	–	–	–	–	1.000
NORTHERN MARKET							
I (0)	.996	.004	–	–	–	–	–
II (1 - 100)	.375	.125	.375	–	.125	–	–
III (101 - 250)	.050	.050	.650	.250	–	–	–
IV (251 - 400)	.077	–	.231	.538	.154	–	–
V (401 - 750)	–	–	.091	–	.818	.091	–
VI (751 - 3,000)	–	–	–	–	–	.944	.056
VII (Over 3,000)	–	–	–	–	–	.111	.889
CENTRAL MARKET*							
I (0)	.997	.001	.001	–	–	.001	–
II (1 - 100)	.278	.639	.083	–	–	–	–
III (101 - 250)	.034	.119	.695	.135	.017	–	–
IV (251 - 400)	.095	–	.191	.476	.238	–	–
V (401 - 750)	–	–	–	.088	.882	.030	–
VI (751 - 3,000)	.027	–	–	–	.027	.946	–
THREE MARKETS COMBINED							
I (0)	.9971	.0018	.0003	–	.0003	.0005	–
II (1 - 100)	.1807	.7229	.0843	–	.0121	–	–
III (101 - 250)	.0412	.0928	.7114	.1443	.0103	–	–
IV (251 - 400)	.0577	–	.1538	.6154	.1731	–	–
V (401 - 750)	–	–	.0167	.0667	.8833	.0333	–
VI (751 - 3,000)	.0161	–	–	–	.0161	.9517	.0161
VII (Over 3,000)	–	–	–	–	–	.0370	.9630

*Because of the small number of firms in the largest categories for the Central Market, only six categories were used for this computation.

Blank cells (–) indicate that there were no movements of firms in this category.

(.135 + .017), is about the same as for a decrease in size, .153 (.119 + .034).

Important observations can be made from these data. First, there is a tendency for small milk handlers to get smaller or to exit from business. Second, there is a strong economic tendency for milk handlers who remain in the market to increase in size. The probability of a milk handler's going out of business decreases as firm size increases. Once a firm reaches the size where it sells over 401 thousand pounds of packaged fluid milk per month, the chances that it will exit are rather remote. The Central Market is the only one in the study where a milk handler of such size failed during the time period under study. The most probable outcome—excluding remaining in the same category—is that firms either increase or decrease gradually, i.e., change in size by one category at a time.

If a new firm enters the Central and Northern Markets, the probability is greatest that it will enter at the level of the smallest active category, II, i.e., producing between 1 and 100 thousand pounds of milk per month. On the other hand, if new firms enter the New Orleans Market, the probability is equally great that they will enter in a size category larger than II.

Statistical analysis shows that factors which affect movements of fluid milk firms among size categories were not significantly different among the three markets.

Size Distribution of Milk Handling Firms

The distribution of economic importance is the relative size distribution of handlers selling milk in the market. The typical milk market in Louisiana was characterized by a relatively small number of handlers. For illustration, there were 83 milk processing and distributing firms in Louisiana in 1952 with average annual sales of 6.7 million pounds. By 1961, the number had decreased to 73 and the average sales per handler had doubled.

Table 5 shows the percentage distribution of firms among size categories in 1956, 1972, and in equilibrium.[1] For example, in Northern Louisiana 33.4 per cent of the fluid milk firms sold less than 101 thousand pounds of milk per month in 1956 (first row, column 2 under Northern Market). Only 6.7 per cent of the firms in that market during 1956 sold in excess of 3 million pounds of milk per month. However, the situation was reversed in the estimated distribution of firms by size categories in 1972.

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[1] The number of firms is in equilibrium when the number entering a size category is equal to the number leaving such size category, i.e., the number of firms per size category will not change.

TABLE 5.—Percentage of Fluid Milk Firms in Each Sales Volume Category, as Reflected by Packaged Fluid Milk Sales, in the Initial Year of Observation, and Estimates for 1972 and Equilibrium, Louisiana Markets

Year	Size category						
	I	II	III	IV	V	VI	VII
	(Thousand pounds per month)						
	0	1-100	101-250	251-400	401-750	751-3,000	Over 3,000
	— — — — — *Percentages* — — — — —						
	NEW ORLEANS MARKET*						
1958	–	34.5	17.3	17.2	10.4	10.3	10.3
1972	–	23.4	10.0	13.3	23.3	20.0	10.0
	NORTHERN MARKET						
1956	–	33.4	13.3	13.3	13.3	20.0	06.7
1972	–	07.7	15.4	07.7	15.4	38.4	15.4
Equilibrium	–	0	0	0	0	66.7	33.3
	CENTRAL MARKET**						
1956	–	20.0	42.9	08.6	11.4	17.1	
1972	–	10.0	15.0	10.0	35.0	30.0	
Equilibrium	–	12.3	12.3	05.5	23.4	46.5	
	THREE MARKETS COMBINED***						
1956	–	21.3	26.7	16.0	13.3	14.7	08.0
1972	–	13.3	13.3	10.0	25.0	28.4	10.0
Equilibrium	–	10.3	08.7	06.6	19.5	38.2	16.7

*Because there was no movement into and out of the two largest categories in the New Orleans Market, in equilibrium all active firms would be in these two categories. Because of the inability to determine the actual number of potential firms, the equilibrium distribution of the firms between these two categories was not estimated.

**Only five categories were used for the Central Market because of the small number of firms in the larger categories.

***These estimates were based upon the observed growth pattern for all firms in Louisiana (the consolidation of observations for the three markets).

Number of Fluid Milk Handlers Estimated for 1972

Estimates of the number of firms in each size category in 1972 were calculated and are shown in Table 6. Provisions were made in the analysis to account for firms entering or leaving the business. These estimates are not affected by the number selected to represent a reservoir of potential entrants. Thirteen milk handlers were estimated to be operating in the Northern Market, and 20 in the Central Market during 1972. These estimates represent a decrease of 13 and 43 per cent in the Northern and Central Markets, respectively, from the number actually operating in January 1956. The number estimated for the New Orleans Market in 1972 was 30, an increase of 3 firms from the number operating in January 1958.

Projections by use of the model indicate the trend toward a smaller absolute number of firms in the industry will continue. Indications are that by 1972 there will be 21 per cent fewer handlers in the three markets combined than the number operating in these markets during 1956, or a total of about 60 milk handlers in Louisiana. This represents a decrease of 13 firms from the number in operation during 1956. By 1972, sixty-three per cent of the firms would be in the largest three categories. It is estimated that these firms will have packaged fluid milk sales in excess of 400 thousand pounds per month. The largest number of firms in any one size category would be 17 in category VI, where the range in sales is from 751 thousand to 3 million pounds of milk per month. Thirty-eight milk handlers would be in size categories larger than category IV, or would have fluid milk sales in excess of 400 thousand pounds per month. Only eight milk handlers would have sales less than 101 thousand pounds per month.

The estimates suggest that in all Louisiana markets, except New Orleans, there would be a larger relative and absolute number of firms in size category VI in 1972 than was in this group during 1956. On the other hand, the number of firms estimated to be in categories II, III, and IV in 1972 was smaller for each market than the number in 1956, with the exception of category III for the Northern Market, which shows no change (Table 5).

Number of Fluid Milk Handlers Estimated for Equilibrium

The concept of "equilibrium" in this study means that the number of firms per size category would not change. However, it recognizes that the size of individual firms may change. But the average number of firms leaving a given size category would be offset by an equal number entering it. The estimated distribution for 1972 shows a tendency to approach equilibrium. In general, the number of handlers in size categories II, III, and IV decreased relatively while the number in V, VI, and VII increased as compared to the initial distribution observed.

TABLE 6.—Estimated Number of Fluid Milk Firms per Size Category, Louisiana Markets, 1972

Size category							
I	II	III	IV	V	VI	VII	
(Thousand pounds per month)							
0	1-100	101-250	251-400	401-750	751-3,000	Over 3,000	Total
Number							
NEW ORLEANS MARKET							
–	–	3	4	7	6	3	23
NORTHERN MARKET							
–	1	2	1	2	5	2	13
CENTRAL MARKET							
–	2	3	2	7	6	–	20
THREE MARKETS COMBINED*							
–	8	8	6	15	17	6	60

*The estimates for each market, including the three markets combined, were developed from four separate probability calculations. Because of this procedure, the number of firms for the state (three markets combined) distribution does not equal the sum of the firms estimated in individual markets.

In equilibrium, 67 per cent of the firms in the Northern Market would be selling between 751 thousand and 3 million pounds of milk monthly (category VI, Table 5). Thirty-three per cent would sell more than 3 million pounds of milk per month (category VII, Table 5). The condition indicated for equilibrium in the Central Market and the three markets combined would be such that about half of the milk handlers would be larger than size category V, i.e., they would be selling in excess of 750 million pounds of milk per month. Also, in equilibrium the largest percentage of firms would be in size category VI in each market except New Orleans.

An equilibrium distribution was not estimated for the New Orleans Market because there were no movements into or out of the two largest size categories during the time period under observation. However, indications are that all firms in the market would be in the two largest size categories.

Fluid Milk Firm Mobility

There was a wide diversity in the observed average lifetime of milk handling firms in different size categories within and between markets. For example, firms remained in size category II in the Northern Market an average of 1.1 years as compared with 13.0 years in the New Orleans Market (Table 7). On the other hand, the average time that firms would be expected to remain in category VI in the New Orleans Market was indicated to be infinity, whereas firms in the other markets would be expected to remain in this size category for only 18 years. The reason for the extreme calculated rigidity in New Orleans is because the handlers in these two size categories did not increase or decrease

TABLE 7.—Mean Lifetime of Fluid Milk Firms in Specific Size Categories, Louisiana Markets

Size category	Mean lifetime			
	1956-62*			
	New Orleans Market	Northern Market	Central Market	Three Markets Combined
(Thous. lbs. per month)	— — — — —	*Average years*	— — — — —	
I (0)	–	–	–	–
II (1 – 100)	13.0	1.1	2.8	3.6
III (101 – 250)	6.0	2.9	3.3	3.5
IV (251 – 400)	6.0	2.2	1.9	2.6
V (401 – 750)	15.0	5.5	8.5	8.6
VI (751 – 3,000)	∞**	18.0	18.5	20.7
VII (Over 3,000)	∞	9.0	–	27.0

*1958-62 for New Orleans Market.

** ∞ means infinity.

their milk sales beyond the limits of the respective size categories during the time period of the analysis. Except in the Northern Market, firms in group IV were more mobile than firms in the other categories in each market. In general, the data in Table 7 indicate that firms in the largest categories are less mobile than those in other size categories. These results suggest that the economic forces stimulating milk handlers to change size categories decrease as the firms become larger.

Indices of firm mobility (in terms of changes in size) in the markets were computed and are shown in Table 8. These indices show the relationship of the mobility of firms in a market in selected time periods to the concept of a "perfectly mobile market."[2] The mobility of firms in the Northern Market in 1956 was 45.8 per cent of that in a perfectly mobile market. It was estimated that by 1972 the mobility of firms in that market would be reduced to about 29 per cent of the mobility of firms in the perfectly mobile market.

The mobility of firms in each of the markets was approximately one and one-half times as great in 1956 as the estimated mobility in 1972 and about twice as great in 1956 as in equilibrium (Table 8). These indices suggest the existence of a consistent decrease in the mobility of firms handling fluid milk in these markets.

This analysis shows a tendency for fluid milk firms to gravitate to the least mobile, larger size categories. The combined influence of the transition of firms to the larger size categories and the tendency for a decrease in firm mobility produces a more rigid market structure.

TABLE 8.—Index of Market Mobility of Fluid Milk Firms, Louisiana Markets, 1956, 1972, and Equilibrium

Market	Index of mobility		
	1956	1972	Equilibrium
New Orleans*	–	–	–
Northern Louisiana	45.8	29.0	20.2
Central Louisiana	24.2	16.0	13.2
Three Markets Combined	15.9	11.3	9.0

*An index of mobility is not presented for the New Orleans Market because there were no movements into or out of the two largest size categories. However, this phenomenon and a comparison of the indices computed for the three markets combined with those for the other two markets suggest that firms in the New Orleans Market are the least mobile.

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[2] A perfectly mobile market may be defined as one in which the probability of moving to a specified size category in one time period is the same for all firms regardless of the size of the firm before the move.

Change in Number and Size of Milk Producing Firms in Louisiana

Measure of Size

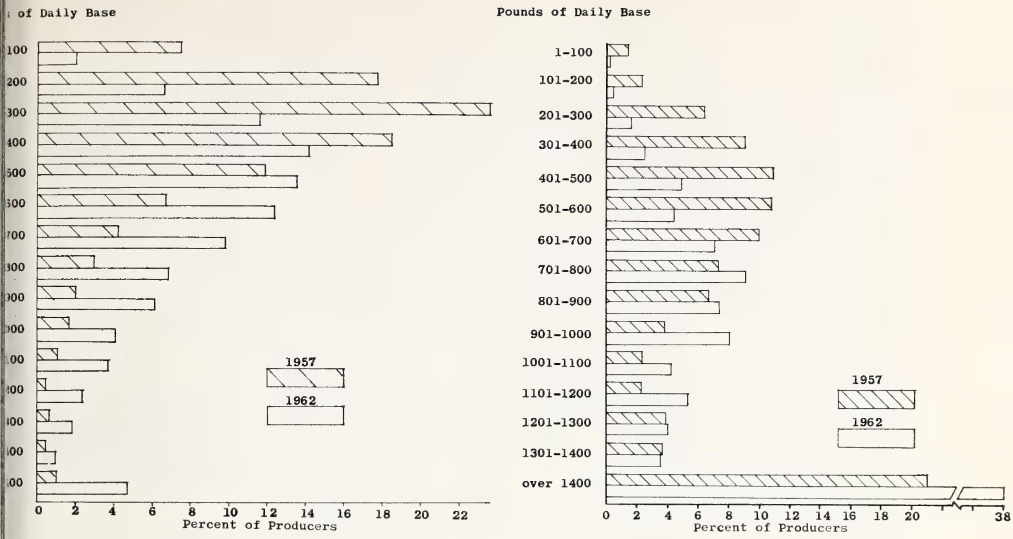
All milk markets in Louisiana operate under federal and/or state marketing regulations. Each of these regulations contains a so-called base rating plan. These plans provide incentives for each dairy farmer to make a deliberate effort to deliver a uniform volume of milk during all months of the year. The average daily volume of milk delivered by a dairy farmer during the base-forming period determines his base, or the volume of milk which he is eligible to contribute to the highest use (price) classification during the flush season of production.

Data available under base rating plans provide information with which to identify growth patterns of individual dairy farmers over a number of years. Also, the number of farmers who discontinue operations and those who enter the market can be identified. It is generally considered that the average daily milk delivery during the base-forming period is a good measure of size of a dairy farmer's business. Therefore, average daily deliveries during the base-forming period were considered as the best measure of size of dairy producing firms in this study. Such data were obtained from records audited by regulatory agencies.

Changes in Milk Producing Firms in Louisiana

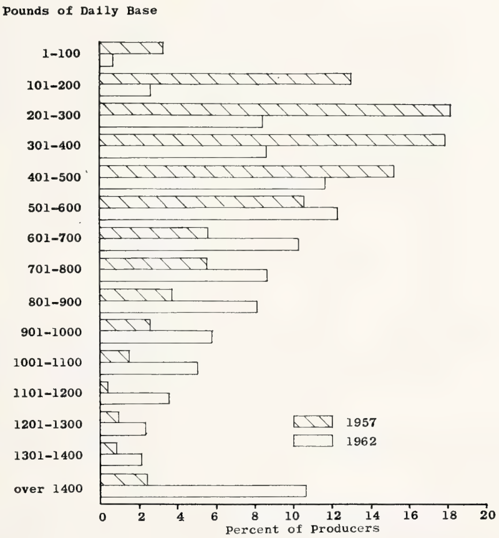
Data showing the total number of dairy farmers who deliver milk to handlers in Louisiana have been available for a number of years. However, data showing the distribution of producers by size categories have been readily available only since the installation of base plans under market regulations. These data indicate that the rate of decline among dairy farmers in Louisiana has been great in recent years. Also, the rate of change in number and size of dairy farm businesses has not been the same for all markets.

During the decade ending in 1962, approximately one out of every four dairy farmers in Louisiana failed. In 1952, 4,652 producers delivered milk to handlers in Louisiana. By 1962, the number had declined to 3,572. Concurrent with the decline in number there has been an increase in size. For illustration, in 1952 the daily average milk delivery per producer in Louisiana was 289 pounds. By 1962, the daily volume of milk delivered per producer had increased to 703 pounds. In the 10-year period preceding 1962, the number of dairy farmers in Louisiana declined by approximately one-fourth, but the total volume of milk production increased two and one-half times. The relative size distribution of producers, as measured by their daily average base pounds, is shown in Figure 2.



New Orleans Market

Northern Market



Central Market

FIGURE 2.—Size Distribution of Milk Producers, Louisiana Markets, Base-operating Periods 1957 and 1962. (Source: Appendix Tables 2-4.)

Number and Size Distribution of Milk Producing Firms in the New Orleans Market

The New Orleans Market is served by more dairy farmers than any other market in the state. There was an average of 2,754 producers delivering milk to handlers in New Orleans in 1952. By 1962 the number had declined to 2,012 (Appendix Table 1).

The average daily volume of milk delivered per producer in the New Orleans Market is the smallest of the markets in the state. In 1957, two-thirds of the farmers serving this market delivered less than 401 pounds of milk per day. Production by this group of dairy farmers accounted for only 25 per cent of the total milk supply. Only 10 per cent of the producers in the New Orleans Market had daily deliveries in excess of 700 pounds in 1957. By 1962, more than half of the milk delivered to the market was supplied by producers whose deliveries exceeded 700 pounds per day. Only 30 per cent of the producers delivered in excess of 700 pounds of milk per day (Appendix Table 2).[3]

Number and Size Distribution of Milk Producing Firms in the Northern Louisiana Market

The average daily volume of milk deliveries by producers in Northern Louisiana is larger than in other areas of the state. Five hundred sixty-six producers supplied milk for the Northern Market in 1952 (Appendix Table 1). The number declined to 505 by 1962 (Appendix Table 3).[4] In 1957, fifty-one per cent of the milk in that market was delivered by producers whose daily milk deliveries were more than 700 pounds. In 1962, fifty-one per cent of the milk was delivered by producers whose average daily deliveries were in excess of 1,100 pounds. In 1957, forty per cent of the producers delivered 500 pounds or less of milk per day. In 1962, only sixteen per cent of the producers were in this size category. In 1957 and in 1962, twenty-five per cent of the producers in the Northern Market delivered 51 per cent of the milk.

Number and Size Distribution of Milk Producing Firms in the Central Louisiana Market

There was an average of 1,332 dairy farmers delivering milk to handlers in the Central Louisiana Market during 1952 (Appendix Table 1). By 1962, the number had declined to 1,039 (Appendix Table 4).[5] Average milk deliveries per farm were almost two and one-half times as great in 1962 as in 1952. Average daily delivery per producer in 1952 was 332 pounds. By 1962, average daily deliveries per producer had increased to 780 pounds. In 1957, fifty-eight per cent of the milk was produced by one-third of the dairy farmers, and their average daily deliveries were 830 pounds. By 1962, fifty-two per cent of the total milk supply came from 29 per cent of the dairy farms, and their average daily deliveries were 1,392 pounds.

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[3] Appendix Tables 2, 3, and 4 include only producers with established bases for the respective years. Appendix Table 1 shows the average number of dairy farmers on the market during the year.

[4] *Ibid.*

[5] *Ibid.*

Growth Patterns and Chances of Survival by Milk Producers in Louisiana

Changes of Milk Producers Among Size Categories

As noted earlier, there was a wide range in the size distribution among dairy farms included in this study. For illustration, the number of producers in each 100-pound size category ranging from less than 100 to more than 1,400 pounds per day is shown in Appendix Tables 2, 3, and 4 for 1957 and 1962.[6] Thus, in order to reflect the growth pattern of all firms among size categories, unequal size categories were used in the analysis (Table 9).

TABLE 9.—Category Intervals of Unequal Sizes Used in Analysis of Milk Producing Firms

Size categories	Category limits
	Pounds of established daily base
A	0
B	1 – 100
C	101 – 300
D	301 – 700
E	701 – 1,500
F	Over 1,500

The objective in establishing size categories was to measure the growth pattern of dairy farms between 1957 and 1962. The growth patterns of milk producers in Louisiana markets are shown in Table 10. The data shown in Table 10 indicate the number of producers by size categories for 1957, the beginning period of analysis, and 1962, the ending period. The table reflects all changes in sizes by each producer between 1957 and 1962. Thus, the "number of producers in 1962" shown across the bottom of the table for each market was the number remaining in each size category in 1962.

It will be observed that Table 10 includes a (0) size category (or no production). This category was necessary in order to account for

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[6] Note that this time period is slightly different from the 1956-62 period used in the analysis of milk handling firms.

TABLE 10.—Growth Patterns of Milk Producing Firms, Louisiana Markets, 1957-1962*

Size category in 1957	Number of producers in 1957	Size category in 1962					
		A	B	C	D	E	F
				(Pounds per day)			
		0	1-100	101-300	301-700	701-1500	Over 1500
(Pounds per day)		—	—	—	*Number of producers*	—	—
NEW ORLEANS MARKET							
A (0)	19,248**	18,426	23	170	390	210	29
B (1 - 100)	178	162	2	3	9	2	–
C (101 - 300)	1,016	625	11	129	201	22	1
D (301 - 700)	1,011	477	3	38	325	161	7
E (701 - 1500)	228	67	–	2	25	108	26
F (Over 1500)	18	6	–	–	1	2	9
Number of producers in 1962	21,699	19,790	39	342	951	505	72
Producers in 1957 = 2,451; in 1962 = 1,909; Dropouts = 1,364; Entrants = 822							
NORTHERN MARKET							
A (0)	26,483**	26,351	1	10	50	59	12
B (1 - 100)	9	6	–	1	2	–	–
C (101 - 300)	146	79	–	25	31	10	1
D (301 - 700)	303	110	1	7	81	99	5
E (701 - 1500)	120	35	–	2	8	50	25
F (Over 1500)	32	7	–	–	1	–	24
Number of producers in 1962	27,093	26,588	2	45	173	218	67
Producers in 1957 = 610; in 1962 = 505; Dropouts = 237; Entrants = 132							
CENTRAL MARKET***							
A (0)	41,369**	41,046	2	35	149	114	23
B (1 - 100)	34	28	1	3	2	–	–
C (101 - 300)	318	226	1	31	49	11	–
D (301 - 700)	501	258	1	14	120	101	7
E (701 - 1500)	150	60	–	1	5	63	21
F (Over 1500)	21	9	–	–	–	4	8
Number of producers in 1962	42,393	41,627	5	84	325	293	59
Producers in 1957 = 1,024; in 1962 = 766; Dropouts = 581; Entrants = 323							
THREE MARKETS COMBINED							
A (0)	87,100**	85,823	26	215	589	383	64
B (1 - 100)	221	196	3	7	13	2	–
C (101 - 300)	1,480	957	12	185	281	43	2
D (301 - 700)	1,815	845	5	59	526	361	19
E (701 - 1500)	498	162	–	5	38	221	72
F (Over 1500)	71	22	–	–	2	6	41
Number of producers in 1962	91,185	88,005	46	471	1,449	1,016	198
Producers in 1957 = 4,085; in 1962 = 3,180; Dropouts = 2,182; Entrants = 1,277							

*This table includes only those producers who had bases on Louisiana markets in 1957 and 1962.

**This number represents potential entrants in 1957. The total number of farms reported in the 1959 Census of Agriculture for the area serving the markets, minus the number of producers, was used to represent this potential. Where producers from one parish were shipping to more than one market, the potential producers were allocated among the markets according to the proportion of producers shipping to the respective markets during the base-forming period of 1958.

***Data were incomplete for a small number of producers for the Central Market and were not included in these observations.

Source: Offices of the Milk Marketing Administrators, New Orleans, Shreveport, and Baton Rouge, Louisiana.

producers who went out of business or new producers who entered production during the period. The reservoir of potential entrants in each market was considered to be the total number of farms in the supply area, less the number of dairy farms. For illustration, there were 19,248 farms in the supply area of the New Orleans Market in 1957 that were not engaged in milk production. In 1962, there were 18,426 farms in that area that were not engaged in milk production. In the period between 1957 and 1962, there were 822 entrants, or farmers who began to produce milk for the New Orleans Market. During the same period there were 1,364 dropouts, or farmers who went out of business. Table 10 shows that in 1957 there were 1,016 dairy farmers in the New Orleans Market who were producing between 101 and 300 pounds of milk per day (size category C) and by 1962, 625 of these had gone out of business and 224 had increased their production to more than 300 pounds per day.

The number of dairy farms in each size category in 1962 is shown in Table 10. In the New Orleans Market, for example, during 1962 there were 39 dairy farmers producing less than 101 pounds of milk per day. There were 342 dairy farmers who produced between 101 and 300 pounds per day and 951 who produced between 301 and 700 pounds per day. Only 577 produced more than 700 pounds of milk per day.

The rate of decline among dairy farmers was large during the period 1957-62. Survival rate was less than 50 per cent. Fifty-three per cent of all dairy farmers who supplied markets in Louisiana during 1957 had either gone out of business or shifted to other markets by 1962 (Table 10). In the New Orleans Market, for example, 1,364 out of 2,451, or 56 per cent, of the dairy farmers went out of business during the five-year period. Of the 1,909 producers supplying the New Orleans Market in 1962, only 1,087 were the same dairy farmers who were supplying the market in 1957. Furthermore, only 985 of these remained in the market during each year between 1957 and 1962.

The "dropout" rate among dairy farmers in the Northern Market was only 39 per cent during 1957-62. The Central Market lost 57 per cent of its producers during the same period.

Chances of Changes in Size by Milk Producing Firms in Louisiana

The analytical procedure used in this study to trace the movement of milk producing firms among size categories was also used to forecast such movements for future time periods. These forecasts are called "transition probabilities" and are generally expressed in "chances" of increasing or decreasing in size or going out of business in a given period of time. The "chances" or probabilities of a producer's moving from one size category to another were calculated for each market and are shown in Appendix Table 5. The table shows the calculated chances of a dairy farmer's moving from each of the size categories indicated on the left side of the table to each of the size categories indicated across the top. For illustration, a dairy farmer in the New Orleans Market who produces between 101 and 300 pounds of milk per day (row 3, column C, Appendix Table 5) has only a 12.7 chance (out of 100) of not changing size category in a five-year period. His calculated chance of going out of business in such a period is 64.2 (row 3, column A). The chance of his increasing to the next size category (301-700) is 19.8 (row 3, column D). Thus, the chance of a dairy farmer in category C going out of business in five years is greater than his chance of remaining in business.

The chance of producers in the two smallest active categories (those producing 300 pounds of milk or less per day) going out of business in five years is greater than 50 per cent in both the New Orleans and Northern Markets (rows 2 and 3, column A). In the Central Louisiana Market, chances are greater than 50 per cent that producers with production of 700 pounds or less per day will go out of business in five years. For the two largest categories in all three markets the greatest probability is for such firms to remain in the same size category.

In general, the probability that a producer will go out of business decreases as size increases. The category with the smallest probability of going out of business is E (701 to 1,500 pounds per day, Appendix Table 5) for the New Orleans and Central producers and F (over 1,500 pounds per day) for producers in the Northern Market. The data in Appendix Table 5 suggest that producers entering the New Orleans or Central Markets are most likely to enter at the size range of 301 to 700 pounds of milk per day or to grow into this size category within four years after entry. In the Northern Market, the probability is that producers will more likely enter the market in category E (701 to 1,500 pounds per day). Also, in all three markets there is a greater tendency for small producers who remain in business to increase in size than to stay in the same size category or to decrease in size.

Larger and Fewer Milk Producing Firms in Future

Data in this study show that during the five-year period 1957-62 the number of small milk producing firms declined and the number in the larger size increased.

The analytical technique used to trace the growth pattern of firms during 1957-62 was also used to estimate the number of producers who

TABLE 11.–Number of Milk Producers per Size Category, by Markets, Louisiana, 1957, 1962, and Estimates for 1972 and Equilibrium

Base operating period	Size categories						
	A	B	C	D	E	F	Total
				(Pounds per day)			
	(0)	(1-100)	(101-300)	(301-700)	(701-1500)	(Over 1500)	
	– – – – – –			*Number*	– – – – –		
			NEW ORLEANS MARKET				
1957	–	178	1,016	1,011	228	18	2,451
1962	–	39	342	951	505	72	1,909
1972	–	29	245	798	665	172	1,909
Equilibrium	–	29	241	794	708	232	2,004
			NORTHERN MARKET				
1957	–	9	146	303	120	32	610
1962	–	2	45	173	218	67	505
1972	–	1	21	106	189	141	458
Equilibrium	–	1	18	97	158	187	461
			CENTAL MARKET				
1957*	–	46	435	684	205	30	1,400
1962*	–	7	114	442	397	79	1,039
1972	–	3	51	237	344	118	753
Equilibrium	–	3	49	223	317	114	706
			THREE MARKETS COMBINED				
1957	–	233	1,597	1,998	553	80	4,461
1962	–	48	501	1,566	1,120	218	3,453
1972	–	27	313	1,119	1,206	460	3,125
Equilibrium**	–	26	303	1,075	1,190	603	3,197

*Data were not available for a small number of individual producers. The number per category was estimated by multiplying the per cent in each category (of the data available on individual producers) times the total number of producers reported for the market in January adjusted to correspond to the current market area.

**The estimates for each market, including the three markets combined, were developed from four separate probability calculations. Because of this procedure, the number of firms for the state (three markets combined) distribution does not equal the sum of the firms estimated in individual markets.

would be in each size category in 1972 and in equilibrium.

The distribution of producers in terms of absolute numbers is shown in Table 11. The number of producers with a base for the New Orleans Market decreased from 2,451 in 1957 to 1,909 in 1962. It was estimated that the same number, 1,909, would be in production in 1972. A slight increase was estimated, to 2,004, for an equilibrium condition. The number of producers with a base in the Northern Market decreased from 610 in 1957 to 505 in 1962; the expected number declined further to 458 in 1972, and then increased slightly to 461 in equilibrium.

The greatest decline in number of producers, both relatively and absolutely, occurred in the Central Market. The number of producers decreased 26 per cent between 1957 and 1962, or from 1,400 to 1,039. Only 753 were estimated for 1972, and a further decline to 706 was

TABLE 12.—Mean Lifetime of Milk Producing Firms per Size Category, Louisiana Markets, 1957-62

Size category	Mean lifetime (five-year period)		Ratio
	1957-62 average	Perfectly mobile market	
(Pounds per day)			
	NEW ORLEANS MARKET		
B (1 - 100)	1.0	1.0	1.0
C (101 - 300)	1.1	1.1	1.0
D (301 - 700)	1.5	1.7	0.9
E (701 - 1500)	1.9	1.5	1.3
F (Over 1500)	2.0	1.1	1.8
	NORTHERN MARKET		
B (1 - 100)	1.0	1.0	1.0
C (101 - 300)	1.2	1.0	1.2
D (301 - 700)	1.4	1.3	1.1
E (701 - 1500)	1.7	1.5	1.1
F (Over 1500)	4.0	1.7	2.4
	CENTRAL MARKET		
B (1 - 100)	1.0	1.0	1.0
C (101 - 300)	1.2	1.1	1.1
D (301 - 700)	1.3	1.5	0.9
E (701 - 1500)	1.7	1.8	0.9
F (Over 1500)	1.6	1.2	1.3
	THREE MARKETS COMBINED		
B (1 - 100)	1.0	1.0	1.0
C (101 - 300)	1.1	1.1	1.0
D (301 - 700)	1.4	1.5	0.9
E (701 - 1500)	1.8	1.6	1.1
F (Over 1500)	2.4	1.2	2.0

indicated for equilibrium. The results indicate a continuous change of producers among size categories. For the New Orleans Market the total number for equilibrium was closely approached in 1962. Equilibrium in the Northern Market would be almost identical with the number indicated for 1972.

Mobility of Milk Producers

Data in this study suggest that milk producers are rather mobile as measured by change in size.

The relationship between the observed average lifetime of producers in specific size categories to the theoretical concept of a perfectly mobile market is shown in Table 12. For illustration, the average dairy farmer in size category C, i.e., producing between 101 and 300 pounds of milk per day, remained in that size group for 1.1 five-year periods. The average lifetime of firms of this size is 1.1 five-year periods for perfectly mobile firms. Thus, producers in this size were considered to be perfectly mobile. The data indicate that producers of each size group were highly mobile and closely approximated a perfectly mobile market.

TABLE 13.—Index of Market Mobility of Milk Producers, Louisiana Markets, 1957, 1972, and Equilibrium

Market	Index of mobility		
	1957	1972	Equilibrium
New Orleans	110.2	91.6	90.6
Northern	98.9	65.4	59.4
Central	118.5	101.0	101.1
Three Markets Combined	105.9	86.5	84.7

Moreover, there was little difference in the observed mean lifetime of firms in given size categories between markets. There were no statistical differences in mobility, whether the computations were based on one-year time periods and equal size categories or a five-year time period and unequal size categories.

An index of mobility by producers in each market was also computed. These indices show the relation of the mobility of producers in selected time periods to the theoretical concept of perfectly mobile firms in a market. These indices ranged from 98.9 in 1957 for the Northern Market to 118.5 in the Central Market. Since these indices do not vary significantly from 100, they indicate that milk producers were highly mobile (Table 13). The projected indices indicate a tendency for only a slight decrease in this mobility. An equilibrium condition would reflect a market mobility index of 90.6, 101.1, and 59.4 for the New Orleans, Central, and Northern Markets, respectively. These results suggest that milk producers will continue to be highly mobile.

Summary and Implications

The number and size of firms in the Louisiana dairy industry changed considerably during the last decade. In general, the number of firms has been declining and the average size of those remaining in business has increased. The pattern of dropout of firms in both the producing and processing segments of the industry has implications for chances of survival and scale of operation of such firms in the future.

Processing and Distributing Firms

Ten fluid milk distributing plants in Louisiana went out of business between 1952 and 1962. These dropouts represented an 11 per cent decline in the total number of firms. Over the same period of time, the average annual volume of milk sales per handler more than doubled. The changes in sales by firms indicated that handlers with the smallest volumes of fluid milk sales tended to get smaller or go out of business, but chances of going out of business declined as size increased. The probability of going out of business was found to be remote when a handler sells in excess of 400 thousand pounds of milk per month.

The analysis of growth patterns among milk processing firms in a study in 1962 indicated that a few large handlers tended to account for the largest share of total milk sales. The three largest fluid milk firms accounted for 40 per cent of total milk sales in Louisiana.[7]

In this study, the six largest firms accounted for more than half of the total fluid milk sales. Fifteen handlers had more than 75 per cent of total sales. This meant that 48 per cent of the firms accounted for only 25 per cent of total sales.

Although individual firms increased in size during the period of study, the change in numbers among size categories remained relatively uniform. Stated differently, all firms tended to grow in size at relatively the same rate.

The trend in growth of firm size is expected to continue in the future. For example, 21 per cent of the fluid milk firms in Northern and Central Markets sold less than 101 thousand pounds of milk per month in 1956. By 1972, only 13.3 per cent of the firms are estimated to be in this size category in all markets. In equilibrium, only 10.3 per cent of the handlers would sell less than 101 thousand pounds of milk per month.

Fluid milk distributing firms tend to gravitate to the larger size categories. In 1956 only 22.7 per cent of the handlers sold more than 750 thousand pounds of milk per month. It is expected (as estimated in this study) that by 1972 more than 38 per cent of the firms will be in these size groups, and in equilibrium more than half of the firms (54.9 per cent) will be in these size groups.

Chances of suvival of milk processing and distributing firms increased as size increased. On the other hand, firms with fluid milk sales of less than 400 thousand pounds per month tend to get smaller or go out of business. Since larger size firms tend to have a higher rate of expectancy for survival, any new entrants into the milk distributing business would be expected to enter in size categories larger than 400 thousand pounds per month. Entrance at that level would require a sizable amount of capital, which may serve to restrict entry.

Milk Producing Firms

The number of dairy farmers in Louisiana has been declining while the daily average volume of milk deliveries per farmer has increased. There were 4,461 producers shipping milk to handlers in Louisiana in 1957. By 1962 the number had declined to 3,453. The decline in number was accompanied by an increase in volume of milk delivered daily per farm. There were 233 producers whose average milk deliveries ranged from 1 to 100 pounds per day in 1957. By 1962 the number in this size category had declined to 48 (Appendix Tables 2, 3, and 4). On the other hand, there were only 633 producers who delivered more than 700 pounds of milk per day in 1957. The number in this size category increased to 2,338, or more than two-thirds of the producers, by 1962.

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[7] William H. Alexander, "Market Concentration in the Fluid Milk Distribution Industry," *Louisiana Rural Economist,* Volume 24, No. 1, February 1962, p. 5.

Generally, the milk producing industry is looked upon as a stable, low risk enterprise. Also, it is generally considered that the number of milk producing firms serving a given market is large enough, and their output small enough, that no single producer's supply significantly affects the total market supply. The findings in this study cast some doubt as to the validity of this belief. During the five-year period 1957-62, 2,182 milk producers who delivered milk to Louisiana markets went out of the dairy business. More than half of these were replaced by new producers (1,277) entering the market. Thus, there was a net loss of 905 producers on the market between 1957 and 1962 (Table 10). On the average, there was only about a 50-50 chance of a producer's remaining in production as long as five years. The probability of going out of business decreased as size of producer increased. Producers with average daily deliveries in excess of 1,200 pounds per day were less likely to go out of production in one year than those in smaller size categories. Irrespective of the firm's size, if it remained in business it was more likely to increase than decrease in size.

It is estimated that the trend toward increasing size of operation will continue for fluid milk producing firms. By 1972, it is estimated that the number and size of dairy farms that produce milk for consumers in Louisiana will reach equilibrium, or a relatively stable number. At that time, it is estimated that the largest number of producers will have milk production approaching 1,500 pounds per day. This situation has implications for future entry of dairy farmers into fluid milk production. Since chances of survival are relatively small for firms with milk deliveries of less than 700 pounds per day, it suggests that it would be well for newcomers on the market to give consideration to entry in a relatively large size category. Entry at a large volume of output (1,500 pounds per day) requires a sizable investment. The high probability of loss of investment for smaller production units may serve as a restriction upon entry into the production of fluid milk by individual farmers.

Appendix

APPENDIX TABLE 1.—Number of Milk Producers and Total Producer Receipts, by Markets, Louisiana, 1952-1962*

Year	New Orleans**		Northern***		Central****	
	Number of producers	Total producer receipts	Number of producers	Total producer receipts	Number of producers	Total producer receipts
	Avg. No.	*Million lbs.*	*Avg. No.*	*Million lbs.*	*Avg. No.*	*Million lbs.*
1952	2,754	242.1	566	89.2	1,332	161.4
1953	2,820	260.4	638	101.7	1,378	178.1
1954	2,764	281.2	656	108.7	1,542	197.9
1955	2,600	294.6	649	120.0	1,587	213.9
1956	2,474	327.2	646	134.1	1,519	228.2
1957	2,258	326.8	657	143.7	1,645	268.6
1958	2,378	339.4	615	142.4	1,313	267.6
1959	2,173	353.7	573	148.8	1,201	256.6
1960	2,163	386.9	572	161.7	1,140	268.7
1961	2,087	428.5	542	167.6	1,062	289.8
1962	2,012	435.1	517	179.4	1,043	302.5

*Producer receipts is the volume of milk delivered to handlers by farmers.

**The New Orleans Market Area was expanded December 1, 1957, to include Terrebonne, Lafourche, and St. Charles Parishes. Producers shipping milk to handlers regulated by the New Orleans Order as a result of the expansion were reported and shown in the Central Louisiana Area prior to the market expansion.

***Prior to August 1958, data for the Shreveport (or Northwest) and Northeast Louisiana Markets were summed for the two areas to approximate the Northern Louisiana Marketing Area under Federal Milk Marketing Order Number 96.

****Data as reported for the Central, Southwest, and Southeast Markets were summed to represent the Central Marketing Area.

Source: *Louisiana Annual Milk Marketing Report 1952-1962* (Division of Milk Testing, Louisiana Department of Agriculture and Immigration).

APPENDIX TABLE 2.—Size Distribution of Milk Producers as Reflected by Established Daily Base Pounds, New Orleans, Louisiana Market, Base Operating Period, 1957 and 1962

Size category	Number of producers per size category	Estimated volume of daily base*	Cumulative volume	Cumulative per cent of volume	Cumulative per cent of producers
Pounds	*Number*	*Pounds*		*Per cent*	
		1957			
Over 1400	25	49,408	49,408	5	1
1301 – 1400	10	13,500	62,908	7	1
1201 – 1300	14	17,500	80,408	9	2
1101 – 1200	9	10,350	90,758	10	2
1001 – 1100	24	25,200	115,958	13	3
901 – 1000	40	38,000	153,958	17	5
801 – 900	50	42,500	196,458	21	7
701 – 800	74	55,500	251,958	27	10
601 – 700	104	67,600	319,558	35	14
501 – 600	165	90,750	410,308	44	21
401 – 500	291	130,950	541,258	58	33
301 – 400	451	157,850	699,108	75	51
201 – 300	578	144,500	843,608	91	75
101 – 200	438	65,700	909,308	98	93
1 – 100	178	8,900	918,208	100	100
		1962			
Over 1400	88	164,025	164,025	14	5
1301 – 1400	17	22,950	186,975	16	6
1201 – 1300	34	42,500	229,475	20	7
1101 – 1200	46	52,900	282,375	25	10
1001 – 1100	70	73,500	355,875	31	13
901 – 1000	76	72,200	428,075	37	17
801 – 900	116	98,600	526,675	46	23
701 – 800	130	97,500	624,175	54	30
601 – 700	187	121,550	745,725	64	40
501 – 600	236	129,800	875,525	75	52
401 – 500	257	115,650	991,175	85	66
301 – 400	271	94,850	1,086,025	94	80
201 – 300	220	55,000	1,141,025	98	92
101 – 200	122	18,300	1,159,325	99	98
1 – 100	39	1,950	1,161,275	100	100

*Estimated by multiplying the number of producers per size category times the mid-point of the category. For the group "over 1400," the number of producers in that size category was multiplied times the average size of the producers in the category.

Source: Office of the Market Administrator, Federal Order 94, New Orleans, Louisiana.

APPENDIX TABLE 3.—Size Distribution of Milk Producers as Reflected by Established Daily Base Pounds, Northern Louisiana Market, Base Operating Period, 1957 and 1962

Size category	Number of producers per size category	Estimated volume of daily base*	Cumulative volume	Cumulative per cent of volume	Cumulative per cent of producers
Pounds	*Number*	*Pounds*		*Per cent*	
		1957			
Over 1400	39	76,050	76,050	21	6
1301 – 1400	10	13,500	89,550	25	8
1201 – 1300	11	13,750	103,300	29	10
1101 – 1200	7	8,050	111,350	31	11
1001 – 1100	8	8,400	119,750	33	12
901 – 1000	14	13,300	133,050	37	15
801 – 900	28	23,800	156,850	44	19
701 – 800	35	26,250	183,100	51	25
601 – 700	55	35,750	218,850	61	34
501 – 600	70	38,500	257,350	72	45
401 – 500	86	38,700	296,050	82	60
301 – 400	92	32,200	328,250	91	75
201 – 300	90	22,500	350,750	98	89
101 – 200	56	8,400	359,150	99	99
1 – 100	9	450	359,600	100	100
		1962			
Over 1400	78	180,180	180,180	38	15
1301 – 1400	13	17,550	197,730	42	18
1201 – 1300	15	18,750	216,480	45	21
1101 – 1200	22	25,300	241,780	51	25
1001 – 1100	19	19,950	261,730	55	29
901 – 1000	40	38,000	299,730	63	37
801 – 900	41	34,850	334,580	70	45
701 – 800	57	42,750	377,330	79	56
601 – 700	51	33,150	410,480	86	67
501 – 600	38	20,900	431,380	91	74
401 – 500	51	22,950	454,330	95	84
301 – 400	33	11,550	465,880	98	91
201 – 300	31	7,750	473,630	99	97
101 – 200	14	2,100	475,730	100	99
1 – 100	2	100	475,830	100	100

*Estimated by multiplying the number of producers per size category times the mid-point of the category. For the group "over 1400," the number of producers in that size category was multiplied times the average size of the producers in the category.

Source: Office of the Market Administrator, Federal Order 96, Shreveport, Louisiana.

APPENDIX TABLE 4.—Size Distribution of Milk Producers as Reflected by Established Daily Base Pounds, Central Louisiana Market, Base Operating Period, 1957 and 1962

Size category	Number of producers per size category*	Estimated volume of daily base**	Cumulative volume	Cumulative per cent of volume	Cumulative per cent of producers
Pounds	*Number*	*Pounds*		*Per cent*	
		1957			
Over 1400	34	64,566	64,566	10	2
1301 – 1400	11	14,850	79,416	12	3
1201 – 1300	13	16,250	95,666	15	4
1101 – 1200	6	7,500	103,166	16	5
1001 – 1100	21	22,050	125,216	19	6
901 – 1000	35	33,250	158,466	24	9
801 – 900	52	44,200	202,666	31	12
701 – 800	63	47,250	249,916	38	17
601 – 700	77	50,050	299,966	46	22
501 – 600	147	80,850	380,816	58	33
401 – 500	211	94,950	475,766	73	48
301 – 400	249	87,150	562,916	86	66
201 – 300	253	63,250	626,166	95	84
101 – 200	182	27,300	653,466	99	97
1 – 100	46	2,300	655,766	100	100
		1962			
Over 1400	110	210,100	210,100	26	11
1301 – 1400	22	29,700	239,800	30	13
1201 – 1300	24	30,000	269,800	33	15
1101 – 1200	36	41,400	311,200	38	18
1001 – 1100	52	54,600	365,800	45	23
901 – 1000	59	56,050	421,850	52	29
801 – 900	84	71,400	493,250	61	37
701 – 800	89	66,750	560,000	69	46
601 – 700	105	68,250	628,250	77	56
501 – 600	128	70,400	698,650	86	68
401 – 500	121	54,450	753,100	93	80
301 – 400	88	30,800	783,900	97	88
201 – 300	87	21,750	805,650	99	97
101 – 200	27	4,050	809,700	100	99
1 – 100	7	350	810,050	100	100

*Data were not available for all individual producers. The number per category was estimated by multiplying the per cent in each category, of the data available on individual producers, times the total number of producers reported for the market.

**Estimated by multiplying the number of producers per size category times the mid-point of the category. For the group "over 1400," the number of producers in that size category was multiplied times the average size of the producers in the category.

Source: Office of the Market Administrator, Louisiana Orders 2 and 3, Baton Rouge, Louisiana.

APPENDIX TABLE 5.—Probabilities of Changes in Size by Milk Producing Firms, Louisiana Markets, 1957-1962

Size category in given time period	Size category in following time period					
	A	B	C	D	E	F
			(Pounds per day)			
	(0)	(1-100)	(101-300)	(301-700)	(701-1500)	(Over 1500)
(Pounds per day)	— — — — — *Number of producers* — — — — —					
			NEW ORLEANS MARKET			
A (0)	.957	.001	.009	.020	.011	.002
B (1 – 100)	.910	.011	.017	.051	.011	–
C (101 – 300)	.642	.011	.127	.198	.021	.001
D (301 – 700)	.472	.003	.038	.321	.159	.007
E (701 – 1500)	.294	–	.009	.109	.474	.114
F (Over 1500)	.333	–	–	.056	.111	.500
			NORTHERN MARKET			
A (0)	.9950	.0001	.0004	.0019	.0022	.0004
B (1 – 100)	.667	–	.111	.222	–	–
C (101 – 300)	.541	–	.171	.212	.069	.007
D (301 – 700)	.363	.003	.023	.267	.327	.017
E (701 – 1500)	.291	–	.017	.067	.417	.208
F (Over 1500)	.219	–	–	.031	–	.750
			CENTRAL MARKET			
A (0)	.991	.001	.001	.003	.003	.001
B (1 – 100)	.824	.029	.088	.059	–	–
C (101 – 300)	.711	.003	.097	.154	.035	–
D (301 – 700)	.515	.002	.028	.239	.202	.014
E (701 – 1500)	.400	–	.007	.033	.420	.140
F (Over 1500)	.429	–	–	–	.190	.381
			THREE MARKETS COMBINED			
A (0)	.985	.000	.003	.007	.004	.001
B (1 – 100)	.887	.013	.032	.059	.009	–
C (101 – 300)	.647	.008	.125	.190	.029	.001
D (301 – 700)	.466	.003	.032	.290	.199	.010
E (701 – 1500)	.325	–	.010	.076	.444	.145
F (Over 1500)	.310	–	–	.028	.085	.577

Blank cells indicate no firms moved into or out of these size categories.

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Soil Potassium and Response of Sugar Cane to Fertilizer Potassium in Louisiana

Ray Ricaud

Louisiana State University and
Agricultural and Mechanical College
Agricultural Experiment Station
Doyle Chambers, Director

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Soil Potassium and Response of Sugar Cane To Fertilizer Potassium in Louisiana

RAY RICAUD[1]

Although Van Helmont in the early seventeenth century considered water as the only nutrient for plants, farmers had been using potassium for many years before that time in the forms of manures and ashes to increase the fertility of the land. It was not until 1840 that the necessity and importance of potassium for the growth of plants were fully established by the chemist Liebig. Since that time considerable progress has been made in developing field and laboratory techniques for determining the availability and requirement of potassium for the growth of plants.

Soil scientists have treated the soil with various chemical agents in an attempt to extract a fraction of the total supply of potassium in the soil that is proportional to the amount of potassium that is available to a crop. A generally accepted extracting solution for available soil potassium has never been found.

An extraction method for available potassium coupled with good analytical procedures may provide one of the most useful means for predicting the most profitable returns from fertilizer potassium. The successful use of an extraction method, however, depends to a large degree upon careful calibration or correlation of the results of the chemical test with response of a crop to the application of fertilizer potassium.

A study of the responses of sugar cane to the application of fertilizers has been in progress in Louisiana for 25 years. Of the three major plant food nutrient elements, potassium has received the least attention. Since the field experiments with fertilizers for sugar cane provided a means for calibrating yield responses to fertilizer and soil potassuim, this study was begun. The primary objectives were (1) to determine total soil potassium, available and exchangeable soil potassium and other cations and other properties of the soils, (2) to determine the yield response of sugar cane to fertilizer potassium, (3) to determine the relationship between soil potassium and yield response, and (4) to make general observations on the removal of potassium by the crop and the relationship between weather and the yield of sugar cane.

Review of Literature

Potassium has been included in the list of essential elements for plant growth since late in the eighteenth century. Since that time, attention has been focused upon the role of potassium in plants, but its exact function has not been definitely determined. A general conception presently held by many investigators is that potassium affects several vital processes in living plants.

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Hartt (*25*) reported that potassium was a specific activator of the enzyme invertase in the synthesis of sucrose in sugar cane plants. Hartt (*26*) later found an accumulation of amino nitrogen with a decrease in protein nitrogen which indicated that the potassium deficient plants were unable to synthesize protein as usual. Richards and Berner (*58*), working on the nutrition of barley, recently reported that accumulation of free amino acids associated with potassium deficiency was due to increased respiration rates in plants. Gruneberg (*23*) found that potassium was associated with high energy transformations in plants and played an important role as a catalyst in the metabolism of plants.

Lawton and Cook (*39*) listed some of the vital processes in living plants affected by potassium as (1) synthesis of simple sugars and starch, (2) translocation of carbohydrates, (3) reduction of nitrates and synthesis of proteins, particularly in meristem tissues, and (4) normal cell division. Barber and Humbert (*5*) have added stomatal movement and water relationship to the list of vital processes affected by potassium.

Soil Fertility Studies in Louisiana

Gouaux (*22*) was among the first to experiment with fertilizers for sugar cane in Louisiana. He reported in 1929 that results of fertilizer demonstrations with plant cane on alluvial sandy clay loam soils confirmed the recommendations of the Experiment Station in that it was unprofitable to fertilize plant cane on lands where a good crop of soybeans was turned under. However, results of three plant cane fertilizer tests conducted on Crowley silt loam showed very positive returns.

O'Neal and Breaux (*50*) and O'Neal and Hurst (*51*) used the Triangle method for testing fertilizers in Louisiana. They reported in 1931 responses of sugar cane to 20 pounds of K_20 per acre on some soil types. O'Neal *et al.* (*52*) reported in 1932 that a 12-4-4 fertilizer ratio mixture produced the most profitable yields of sugar cane. O'Neal and Schreiner (*53*) reported results from fertilizer trials on Lintonia silt loam which showed that the greatest and most consistent increases over unfertilized plots were made with 36-0-24 or 24-0-36 fertilizer mixtures.

Holmes (*29*) worked with soils in the sugar cane area and reported in 1937 that exchangeable potassium was found to be high, but on several fields there was some response to potassium as more and more nitrogen was added. He found a fairly good correlation between the exchangeable potassium in the soil and the response of sugar cane to fertilizer potassium. Response to potassium was expected at that time where the exchangeable potassium was below 260 ppm. Hendrix (*27*) reported in 1937 that nitrogen was the only nutrient found to be a limiting factor in the production of sugar cane on Sharkey soils. The soils studied were so high in available phosphorus, potassium and calcium that the addition of these elements showed relatively little effect in increasing the yield of sugar cane.

Hurst and Holmes *(35)* in 1938 described the Schreiner triangle method for fertilizer trials and illustrated its application with results from several fertilizer experiments with different varieties of sugar cane on several major soil types. They obtained yield responses from added fertilizer potassium on Lintonia and Iberia soils. They also predicted that as more and more nitrogen is added to the soil a point will be finally reached where nitrogen plus phosphorus or potassium or phosphorus and potassium may give a better sugar cane yield than nitrogen alone. In the western part of the sugar cane area, they found that the deficiencies of phosphorus and potassium were greater than in the eastern part. They extracted exchangeable potassium with a one-twentieth normal HCl solution at 1:10 soil to solution ratio, and obtained a high negative correlation between exchangeable potassium in the soil and response of sugar cane to fertilizer potassium.

Davidson *(16)*, of the Houma station, reported in 1942 that average results over a period of years indicate that an application of 36 to 40 pounds per acre of nitrogen only was required to produce a normal crop of sugar cane in Louisiana. He also found that with the same amounts of fertilizer there were significantly different yield responses with different varieties of sugar cane *(15)*. Presently, Davidson is recommending 80 to 160 pounds of nitrogen and additions of phosphorus and potassium where soil tests indicate these to be low.

Walker and Sturgis *(75)* reported that soil fertility studies in the sugar cane area begun in 1940 showed that wide variations existed in the contents of available nutrient elements as determined by chemical methods. The Mississippi (Pleistocene) terrace soils were found to be relatively low in available nitrogen, phosphorus and potassium. Heretofore, these soils were considered to be deficient only in nitrogen for sugar cane. They found that the best adapted fertilizer treatment in 1945 was 60 pounds nitrogen, 25 pounds P_20_5 and 40 pounds of K_20 per acre.

DeMent and Sturgis *(17)* reported in 1952 results obtained with sugar cane on Lintonia silt loam. The additions of 40 pounds of P_20_5 and 60 pounds of K_20 with 100 pounds of nitrogen per acre increased yield approximately 7 tons per acre over that with 100 pounds of nitrogen alone or 16 tons per acre over the check.

Sturgis and Byrnside *(70)* summarized 10 years' work from 1942 to 1951 with complete fertilizers on sugar cane. They reported that the observations of Gouax through many years of varietal test field work and analytical soil studies by Worsham and Sturgis *(76)* had by 1941 established the fact that the productive capacity and the available nutrient content of the soils in the sugar cane area were variable and in many cases low. Soil nitrogen was generally low. Forty per cent of the soils tested were so low in easily soluble phosphorus that it was apparent that sugar cane on these soils could be expected to respond to added phosphates. More than 50 per cent of the soils tested were low in exchangeable potassium and response to fertilizer potassium could be expected on the soils testing low in potassium. It was also recognized that other factors such as high soil acidity associated with low availability of calcium and especially of magnesium, the development of a plow pan in the soil, and soil acidity in relation to the choice of nitrogen fertilizers might affect the response of sugar cane to complete fertilizers.

Peterson (*56*) worked with soils in the rice area of Louisiana. He reported that correlations between response of rice to fertilizer potassium and exchangeable soil potassium before treatment were consistently negative, but not statistically significant. Of the soils studied, no soil having less than 2,600 ppm. total potassium in the surface soil failed to give a significant yield increase from added fertilizer potassium. Rice on soils testing less than 80 ppm. of exchangeable potassium showed some response to added fertilizer potassium.

Soil Fertility Studies in Florida

Sugar cane yield responses from additions of fertilizer potassium have been obtained by several workers in Florida. Stevens (*68*) reported in 1933 that fertilizer potassium was found to be the most important fertilizer for early use on many soils in the production of sugar cane. Striking tonnage increases were obtained with moderate applications of potassium on the first crop grown on freshly broken land of good quality. Bregger and Bedsole (*9*) in 1953 reported increases in sugar cane and sugar yields from applications of fertilizer potassium. According to Legrand (*41*) sugar cane grown on organic soils in Florida did not respond to additions of nitrogen, but on most fields yields were higher after the application of potassium.

Soil Fertility Studies in Hawaii

Halliday (*24*) has reviewed the world-wide literature on the manuring of sugar cane. Several workers in foreign countries have reported responses of sugar cane to fertilizer potassium. Humbert (*33*) did extensive work with potassium fertilization in the Hawaiian sugar industry. He reported that responses to fertlizier potassium ranging from one to three tons of sugar per acre were correlated with exchangeable soil potassium. Significant responses in sugar yields were obtained where the level of exchangeable potassium was 190 pounds or less per acre foot. According to Humbert, the conversion of reducing sugars to sucrose prior to harvest time is believed to be related to the balance between nitrogen and potassium. Adequate potassium must be available to utilize the "unused" nitrogen to bring about a stage of maturity where the bulk of the reducing sugars are converted to sucrose.

Humbert (*32*) reported results from 31 replicated experiments which showed that the critical level of exchangeable soil potassium was 75 ppm. Significant increases from fertilizer potassium were obtained in some cases between 75 and 110 ppm. Above 110 ppm. fertilizer potassium was applied strictly for insurance purposes. He pointed out that the only exceptions were found in the low volume weight soils where for a given level of potassium expressed in ppm. the amount of potassium per acre foot was considerably lower than in the high volume weight soils for which the critical level was initially established. In the amounts-of-potassium tests, 40 per cent of the experiments showed significant gains from fertilizer potassium.

Ayres and Hagihara (*4*) obtained results from 57 experiments in Hawaii similar to those obtained by Humbert. They found an increase of 175 per cent in yield at the extremely low soil potassium level of 30 ppm. and about 35 per cent at 40 ppm. Above 40 ppm. the response curve dropped less until at about 100 ppm. potassium it became horizontal, suggesting little likelihood of response to the addition of fertilizer potassium at soil potassium levels in excess of 100 ppm. The potassium was extracted with ammonium acetate adjusted at pH 7.0. Very few experiments in which supplies of potassium were below 75 ppm. failed to respond. According to Baver (*6*) the deficiency-sufficiency range for available potassium in sugar cane soils was 100-162 ppm. Magistad (*46*) reported increased yields of pineapple from potassium applied to soils containing 80 ppm. or less of exchangeable potassium.

Silva, Darroch and Humbert (*65*) summarized the results of 22 potassium experiments on the island of Hawaii and 90 potassium experiments on the island of Kauai conducted from 1950 to 1957. Polynomial yield equations which included terms for soil potassium, the square root of applied potassium and their product were developed to describe the yield response for each of these islands.

Burr (*10*) in Hawaii reported potassium responses measured in tests on individual plantations. The response to added fertilizer potassium was remarkably uniform in spite of the wide range of absolute values resulting from variable levels of soil potassium on the different plantations.

Although responses of sugar cane to fertilizer potassium were measured where the available soil potassium was low, it is conceivable that the misuse of fertilizer may result in little or no response and possibly harmful effects. Clements (*14*) found that when all the potassium was applied under the seed piece at planting time he obtained no response, while subsequent studies showed the soils to be seriously deficient in potassium. Clements also pointed out that excessive applications of fertilizer potassium increased the potassium content of the milled cane so high that the KCl crystallized sooner than the sucrose in the sugar boilers, thus blocking the drainage system of the centrifuges.

Soil Fertility Studies in Other Countries

Bonnet (*7*) reported in Puerto Rico significant responses of sugar cane to 90 pounds of K_20 per acre per crop per year. Innes and Chinley (*36*) in Jamaica found that the average response of sugar cane to potassium varied according to soil type. The mean percentage response to 130-163 pounds K_20 applied per acre varied from 3.5 per cent on irrigated clay alluvia to 77.6 per cent on dry inland basin alluvia soils. Where there was a yield response to the addition of fertilizer potassium, juice quality was also improved. Walker (*74*) in British Guiana agreed that soil type was a major factor in measuring yield responses from fertilizer potassium. He obtained increases in yield of 5 per cent on clay soils and up to 13 per cent on lighter soils.

Aughtry and Lunin (*3*) in the Dominican Republic reported no appreciable increase in sugar cane yield from applying potassium at a rate of 119 pounds of K_2O per acre. Aguirre (*1*) in Brazil reported an average response of 5.3 tons of sugar cane to 87 pounds of K_2O added per acre. In Trinidad, Carey and Robinson (*13*) and Jack (*37*) reported responses to fertilizer potassium. Jack concluded that scorching of sugar cane leaves associated with applying sulphate of ammonia was due to potassium deficiency, probably induced by the nitrogen application. Saint (*59*) in Barbados found that, on coral limestone soils, if the top soil contained less than 116-133 ppm. of exchangeable potassium the yield of sugar cane was limited by a deficiency of potassium.

Fertilizer trials in South Africa (*63*) showed that a high correlation existed between soil potassium and yield response of sugar cane to fertilizer potassium. Yield responses were obtained where the soil K_2O level was 250 pounds or less per acre. Lintner (*42*) in Natal indicated that potassium deficiency symptoms in sugar cane were becoming more widespread. Du Toit (*19*) reported a 1,300 per cent increase in potash usage for sugar cane during a nine year period ending in 1959.

Hodnett (*28*) used an equation based on Mitscherlich's equation for estimating responses of sugar cane to fertilizer applications in experiments conducted in the British Colonial and Commonwealth Territories. He reported that fertilizer nitrogen had a depressing effect while fertilizer potassium increased the sugar percentage. The effect of fertilizer phosphate was generally small and irregular.

Locsin (*43, 44*) and Smith (*66*) conducted sugar cane fertilizer experiments in the Victorias. They recommended fertilizer ratios that included 81 to 130 pounds of K_2O per acre.

According to Halliday (*24*) the present world-wide recommendations of fertilizer potassium for sugar cane at various levels of soil potassium are generally as follows:

More than 130 ppm. exch. K—No fertilizer K_2O recommended.
130 to 100 ppm. exch. K—82 pounds per acre K_2O recommended.
100 to 70 ppm. exch. K—130 pounds per acre K_2O recommended.
Less than 70 ppm. exch. K—163 pounds per acre K_2O recommended.

Potassium Deficiency in Sugar Cane

Hartt (*26*) reported in 1929 that potassium deficient sugar cane plants had greater percentages of total sugars, reducing sugars and sucrose than the plants supplied with potassium. Hartt (*25*) also reported that the percentage of iron in most tissues, especially in the nodes of sugar cane, was higher under conditions of potassium shortage. Humbert (*34*) was not in complete agreement with Hartt on the sugar content of sugar cane in that he found that potassium deficiency resulted in higher reducing sugars, lower sucrose, lower purities and higher tons millable cane per ton sugar.

Martin (*47*) found that the first visible potassium deficiency symptom in sugar cane was the retardation in growth. He observed that the stalks tapered rapidly toward the growing point and that the tops assumed a fan-like appearance. He reported that older leaves died back from the tips and margins, resulting in a definite firing of the leaf edges, and changed from a dark green to a pale yellowish color with numerous minute chlorotic spots. According to Venema (*72*) young leaves of potassium deficient sugar cane plants were dark green becoming pale yellow with definite reddish discolorations on the upper surfaces of the midribs.

According to Hartt (*25*) the variations in potassium content of sugar cane leaves with age have led many investigators to conclude that potassium migrated from the leaves back to the stalk before the leaves became physiologically inactive.

Effects of Fertilizer Potassium on Juice Quality

Although considerable work has been done on the effects of fertilizers on the quality of sugar cane juice, the effect of fertilizer potassium on percentage sucrose is still a controversial issue.

Geerlige (*20*) reported in 1911 that the potassium content of sugar cane juice was used as a criteria of a probable high sugar content and a high purity at maturity. He found that plants having the lowest potassium content ultimately contained the best sugar content and quotient of purity of the juice. This was not in agreement with the findings of most workers.

Verret (*73*) found that fertilizer potassium had no effect on the juice quality of sugar cane. Alexander (*2*) reported the results of a six-year study in which he showed that the sucrose content of sugar cane may have been improved by potassium fertilization. Naquin (*48*) reported that sugar cane receiving fertilizer potassium and nitrogen gave better quality juice than nitrogen alone. According to Ulrich (*71*) the sugar content of sugar beet roots is markedly reduced at high levels of fertilizer nitrogen. Borden (*8*) concluded that the more fertilizer potassium and nitrogen applied to sugar cane under poor light conditions, the greater the moisture content of the cane, and consequently the lower the juice quality.

Samuels (*60*) and Samuels and Landrau (*61, 62*) in Puerto Rico have done the most extensive work on the influence of fertilizers on sucrose content of sugar cane. They found that fertilizer potassium applications increased the sucrose content of sugar cane only when significant increases in cane tonnage were obtained.

Experimental Material and Methods

Soil types of the sugar cane area of Louisiana have been generally described by Lytle and Sturgis (*45*). Detailed descriptions of the soil types studied are given in Soil Survey Reports of the parishes published by the United States Department of Agriculture, the Soil Conservation Service and Louisiana Agricultural Experiment Station. A large percentage of the sugar cane is grown on the relatively immature and fertile younger alluvial soils of the Mississippi and Red River flood plains. The Commerce, Mhoon and Sharkey series are alluvial soils derived from Mississippi alluvium. Yahola series is a reddish and more or less calcareous alluvial soil found in the flood plains of the Red River and its distributaries.

Geologically older soils of the Cypremort, Baldwin, Jeanerette, Iberia and Patoutville series were developed on low-lying stream terraces which were probably formed by the Mississippi River and its distributaries in the late Pleistocene or the early Recent. The soils of the Richland and Olivier series are the oldest soils in the sugar cane area and occur on the Pleistocene Mississippi terraces.

Soil and Plant Material

Samples and data from 49 fertilizer experiments with sugar cane conducted at 28 experimental locations in the sugar cane area by the Agronomy Department of the Louisiana Agricultural Experiment Station during a 10-year period from 1954 through 1963 were used in this study.

The fertilizer treatments in each experiment were replicated three times in a randomized block design. The plot size was approximately one-tenth acre. Fertilizers were mixed from ammonium nitrate, 20 per cent superphosphate and 60 per cent muriate of potash. Fertilizers were applied by hand in the off-bar furrow in spring. Fertilizer treatments applied to plant and stubble cane were as follows:

Plant Cane		Stubble Cane	
1954 to 1959 $N-P_2O_5-K_2O$ Lbs./A.	1960 to 1963 $N-P_2O_5-K_2O$ Lbs./A.	1954 to 1959 $N-P_2O_5-K_2O$ Lbs./A.	1960 to 1963 $N-P_2O_5-K_2O$ Lbs./A.
0-0-0	0-0-0	0-0-0	0-0-0
40-0-0	40-0-0	80-0-0	80-0-0
40-0-60	40-0-80	80-0-60	80-0-80
40-40-0[1]	40-40-0	80-40-0[1]	80-40-0
40-40-60	40-40-80	80-40-60	80-40-80
60-0-0	80-0-0	100-0-0	120-0-0
60-0-60	80-0-80	100-0-60	120-0-80
60-40-0[1]	80-40-0	100-40-0[1]	120-40-0
60-40-60	80-40-80	100-40-60	120-40-80
80-0-0	120-0-0	120-0-0	160-0-0
80-0-60	120-0-80	120-0-60	160-0-80
80-40-0[1]	120-40-0	120-40-0[1]	160-40-0
80-40-60	120-40-80	120-40-60	160-40-80

[1] Fertilizer treatments used only in 1958 and 1959 experiments.

Three rates of nitrogen were applied to both plant and stubble cane, but lower rates were applied to plant than to stubble cane. Two rates of phosphorus and two rates of potassium were applied to both plant and stubble cane. A 3 x 2 x 2 factorial type experiment with nitrogen, phosphorus and potassium was used after 1957. Due to increasing responses to fertilizer nitrogen and potassium, higher rates of each were used after 1959. When possible the fertilizer experiments were continued at the same location during the plant, first and second stubble cane years.

Cultivation and the control of weeds, diseases and insects were followed during the growing season according to plantation practices at each location. Precipitation was measured at each location with rain guages. At harvest, the sugar cane on each plot was topped, cut and piled in a heap row with a cane harvester. After burning the dry leaves, the millable cane was loaded on tractor carts and weighed. The percentage trash in the millable cane was determined and yield was recorded in tons per acre of clean cane.

A 10-stalk sample was collected from each plot, and sucrose, brix and purity analyses were made in the mill laboratory for each experimental location. Percentage sucrose and cane yield were used to determine the amount of sugar produced on each plot. Response of sugar cane to fertilizer potassium was measured by comparing the N-K treatment with the N treatment and the N-P-K treatment with the N-P treatment at each of the three N levels.

A surface soil sample was taken in spring prior to fertilization at each of the 28 experimental locations. The samples were air-dried, pulverized, passed through a 2 mm. sieve and stored in ice cream cartons to await analysis.

Methods for Soil Analysis

Surface soil samples from the 28 experimental locations were analyzed for available or extracted soil K, Ca, Mg and Na. The available cations were extracted with 0.1 N hydrochloric acid and with 1.0 N ammonium acetate buffered at pH 7.0 at 1:10 and 1:20 soil to solution ratios. This was done by weighing, in duplicate, 10 grams and 5 grams of air-dried soil for the 1:10 and 1:20 ratios, respectively, into 250 ml. flasks and adding 100 ml. of the extractant to each flask. The samples were then shaken for 20 minutes on a mechanical shaker and filtered immediately through Whatman's No. 12 filter paper into sample bottles. The K, Ca, Mg and Na determinations of the filtrate were made with a Beckman Model DU spectrophotometer, with flame attachment and photomultiplier assembly.

The soil samples were analyzed for exchangeable soil K, Ca, Mg and Na by the method described by Peech *et al.* (*55*). A 25 gram sample from each soil was weighed in duplicate into 250 ml. flasks. Then 100 ml. of 1.0 N ammonium acetate, buffered at pH 7.0, were added, and the mixture was shaken for 30 minutes and allowed to stand over night. The samples were filtered in Buchner funnels fitted with Whatman's

No. 12 filter paper, with gentle suction applied. The samples were leached with an additional 250 ml. of the extractant in 25-50 ml. portions. After filtration, the exchangeable cations in the filtrates were determined in the same manner described for the available cations.

Exchangeable hydrogen in each soil sample was determined by the barium acetate method as described by Jackson (*38*).

Cation exchange capacity of each soil was determined by the summation of the exchangeable bases and exchangeable hydrogen. The percentage base saturation was calculated by dividing the base exchange capacity by the cation exchange capacity and multiplying by 100.

Total potassium in each soil sample was determined by the hydrofluoric acid digestion method as described by Jackson (*38*). Duplicate 0.5 gram samples of soil which had been ground to pass through a 100 mesh sieve were weighed into platinum crucibles and treated with 10 drops of concentrated sulfuric acid and 15 ml. of 48 per cent hydrofluoric acid. The crucibles were heated almost to dryness, then treated with an additional 5 ml. of hydrofluoric acid and heated to dryness. The residues were dissolved in 250 ml. beakers containing a weak solution of nitric acid, then heated to dryness and treated again with 4:1 nitric-perchloric acids to completely oxidize the organic matter. The residues were taken up with 10 ml. of 5 N hydrochloric acid and filtered into 100 ml. volumetric flasks and made up to volume. The total potassium in the filtrates was determined in the same manner described for the available soil potassium.

The pH of the soil samples was determined with a Beckman Zeromatic pH meter equipped with a glass electrode and a saturated calomel reference electrode.

Organic matter in each soil sample was determined by the dry combustion method. The apparatus used and procedures followed were described by Piper (*57*).

Total nitrogen in each soil sample was determined by the Kjeldahl method as described by Jackson (*38*).

Percentages of sand, silt and clay in each soil sample were determined by the hydrometer as modified by Patrick (*54*). Textural class of the soils was determined as described in the Soil Survey Manual, United States Department of Agriculture Handbook, 1937, page 18.

Methods for Statistical Analysis

The statistical analysis methods used are described by Snedecor (*67*) and LeClerg (*40*). Linear and curvilinear regression equations and simple correlation coefficients were calculated for some of the chemical and physical properties of the 28 soils studied.

An analysis of variance was calculated on the yield data obtained from each of the 49 fertilizer experiments to determine the significance of the response due to the additions of fertilizer potassium. Regression equations were obtained to show the relationship between extractable soil potassium and response of sugar cane to fertilizer potassium.

Experimental Results and Discussion

Experimental locations and the soil type at each location where the fertilizer experiments with sugar cane were conducted are shown in Table 1. Twenty-two experiments were conducted at 12 locations (Nos. 1-12) on Alluvial soils of the Mississippi and Red River flood plains. Twenty-seven experiments were conducted at 16 locations (Nos. 13-28) on Older Alluvial or Terrace soils bordering Bayou Teche in the western section of the sugar cane area.

Chemical and Physical Properties of the Soils

Data obtained on the chemical and physical properties of the soils

TABLE 1.—Soil Types and Location of Experiments with Fertilizers for Sugar Cane on Alluvial Soils (Nos. 1-12) and Older Alluvial or Terrace Soils (Nos. 13-28)

Exp. Loc. No.	Soil Type	Depth Sampled Inches	Plantation	Year of Experiment		
				Plant Cane	1st Stubble	2nd Stubble
1	Yahola sil	0-8	Edgefield	1959		
2	Commerce l	0-8	Smithfield	1954		1956
3	Commerce sil	0-8	Smithfield	1959	1960	
4	Commerce sil	0-8	Alma	1962	1963	
5	Mhoon l	0-7	Little Texas	1954	1955	1956
6	Mhoon sil	0-7	Little Texas		1958	1959
7	Mhoon sil	0-8	Warren Harang		1963	
8	Mhoon sil	0-8	Smithfield		1958	
9	Mhoon sil	0-8	Little Texas	1960	1961	1962
10	Mhoon sicl	0-8	Pecan Tree		1960	1961
11	Mhoon sic	0-8	Caldwell		1963	
12	Sharkey c	0-8	Pecan Tree	1962	1963	
13	Cypremort sil	0-8	Alice "B"		1961	
14	Baldwin sil	0-7	Alice "B"	1956	1957	1958
15	Baldwin sil	0-7	Alice "B"	1962	1963	
16	Baldwin sic	0-5	O'Neil	1958	1959	1960
17	Jeanerette sil	0-8	Alice "B"	1959	1960	
18	Jeanerette sil	0-8	St. John	1963		
19	Jeanerette sil	0-8	Patout		1961	
20	Jeanerette sil	0-8	Patout	1962	1963	
21	Iberia sil	0-7	Katy	1955	1956	
22	Iberia sil	0-7	Cherry Grove	1956		
23	Patoutville sil	0-6	Vaufrey	1955		
24	Patoutville sil	0-6	Vaufrey	1956		
25	Richland sil	0-7	Young's Ind.	1954	1955	
26	Richland sil	0-7	Young's Ind.	1956		
27	Richland sil	0-7	Billeaud		1957	
28	Olivier sil	0-8	Young's Ind.	1959	1960	1961

studied are presented in Tables 2 through 6. Simple correlation coefficients among the properties of the soils are presented in Table 7.

Potassium Content of the Soils

Data on soil potassium are shown in Table 2. Available soil potassium extracted with either 0.1 N hydrochloric acid or with 1.0 N ammonium acetate was slightly higher at the 1:20 than at the 1:10 soil to solution ratio. The ammonium acetate solution extracted con-

TABLE 2.—Potassium Content of Alluvial Soils and Older Alluvial or Terrace Soils by Various Methods of Extraction

Exp. Loc. No.	Available Soil K: 0.1 N HCl 1:10	0.1 N HCl 1:20	1.0 N NH_4OAc 1:10	1.0 N NH_4OAc 1:20	Exchangeable K		K Saturation	Total K
	ppm.	ppm.	ppm.	ppm.	ppm.	me./ 100 g.	%	%
1	75	93	79	88	94	0.24	1.3	1.76
2	89	96	88	95	113	0.29	2.5	2.03
3	76	86	82	85	110	0.29	1.8	2.06
4	79	92	76	101	126	0.32	2.8	1.91
5	108	117	112	116	127	0.32	1.8	1.96
6	65	78	67	74	85	0.21	1.3	2.10
7	103	111	121	124	141	0.36	1.7	1.79
8	51	57	49	54	65	0.16	1.7	1.90
9	73	78	74	77	72	0.18	1.1	2.16
10	100	110	121	122	151	0.39	1.4	2.19
11	212	227	267	265	299	0.76	2.2	1.96
12	249	311	398	406	585	1.49	2.9	2.19
13	33	47	44	48	46	0.12	1.1	1.60
14	52	61	54	62	65	0.16	1.0	1.77
15	62	66	58	61	76	0.19	1.0	1.65
16	131	155	174	190	201	0.51	1.8	1.95
17	82	104	88	95	108	0.28	1.0	1.90
18	73	80	74	80	88	0.23	1.0	1.51
19	46	59	47	55	56	0.14	0.5	1.26
20	76	80	74	76	85	0.21	1.2	1.20
21	58	67	56	63	68	0.17	0.8	1.62
22	75	85	64	75	73	0.19	0.5	1.20
23	69	75	81	90	84	0.21	2.0	1.22
24	44	47	47	54	50	0.13	1.5	1.26
25	74	82	93	95	98	0.25	1.8	1.44
26	85	94	106	108	110	0.28	2.2	1.45
27	62	69	72	79	84	0.21	1.9	1.38
28	46	58	56	62	67	0.17	1.4	1.43

siderably more potassium than the hydrochloric acid solution at either ratio, particularly from soils high in clay content. Available potassium extracted with 0.1 N hydrochloric acid at the 1:20 ratio varied from 57 ppm. in Mhoon silt loam to 311 ppm. in Sharkey clay, with an average of 121 ppm. for the Alluvial soils. In the Older Alluvial or Terrace soils, the available potassium varied from 47 ppm. in Cypremort silt loam to 155 ppm. in Baldwin silty clay with an average of 77 ppm. Wyatt and Patrick (*77*) found that the available potassium by this method varied from 30 to 164 ppm. in this group of soils. Available potassium extracted with 1.0 N ammonium acetate at the 1:20 ratio varied from 54 ppm. in Mhoon silt loam to 406 ppm. in Sharkey clay with an average of 134 ppm. for the Alluvial soils and from 48 ppm. in Cypremort silt loam to 190 ppm. in Baldwin silty clay with an average of 81 ppm. for the Terrace soils. Available potassium extracted by any method studied was higher in the Alluvial soils than in the Older Alluvial or Terrace soils. Worsham and Sturgis (*76*) also found a wide variation in the availability of native potassium in soils of the lower Mississippi delta.

Exchangeable potassium varied from 65 to 585 ppm. with an average of 164 ppm. in the Alluvial soils and from 46 to 201 ppm. with an average of 85 ppm. in the Older Alluvial or Terrace soils. Driskell (*18*) found that the exchangeable potassium in five major soil series of the Older Alluvial or Terrace soil group varied from 39 to 195 ppm. with an average of 101 ppm. The significant regression curve in Figure 1 and correlation coefficient in Table 7 show the association between available potassium and exchangeable potassium. Available potassium and exchangeable potassium were highly correlated with percentage clay in the soils. Figure 2 shows the relationship between exchangeable potassium and percentage clay.

Total potassium content of the soils varied from 1.76 per cent in Yahola silt loam to 2.19 per cent in the Mhoon silty clay loam and in Sharkey clay with an average of 2.00 per cent for the Alluvial soils. Total potassium varied from 1.20 per cent in Jeanerette silt loam and in Iberia silt loam to 1.95 per cent in Baldwin silty clay. The average for the Older Alluvial or Terrace soils was 1.49 per cent. Golden (*21*) found that Commerce, Yahola, Richland, Jeanerette and Baldwin soils contained 1.80, 1.68, 1.25, 1.69 and 1.74 per cent total potassium, respectively. Holmes and Hearn (*31*) reported that the Robinsonville, Sharkey and Miller soils contained as high as 2.48, 2.67 and 3.04 per cent total K_2O, respectively. The data show that available and exchangeable potassium were 0.60 and 0.81 per cent, respectively, of the total potassium in the Alluvial soils. Available and exchangeable potassium were 0.52 and 0.57 per cent, respectively, of the total potassium in the Older Alluvial or Terrace soils. Figure 3 shows that the association between total potassium and exchangeable potassium in the Alluvial and Older Alluvial or Terrace soils was barely significant. A similar association was found between total potassium and available potassium in the

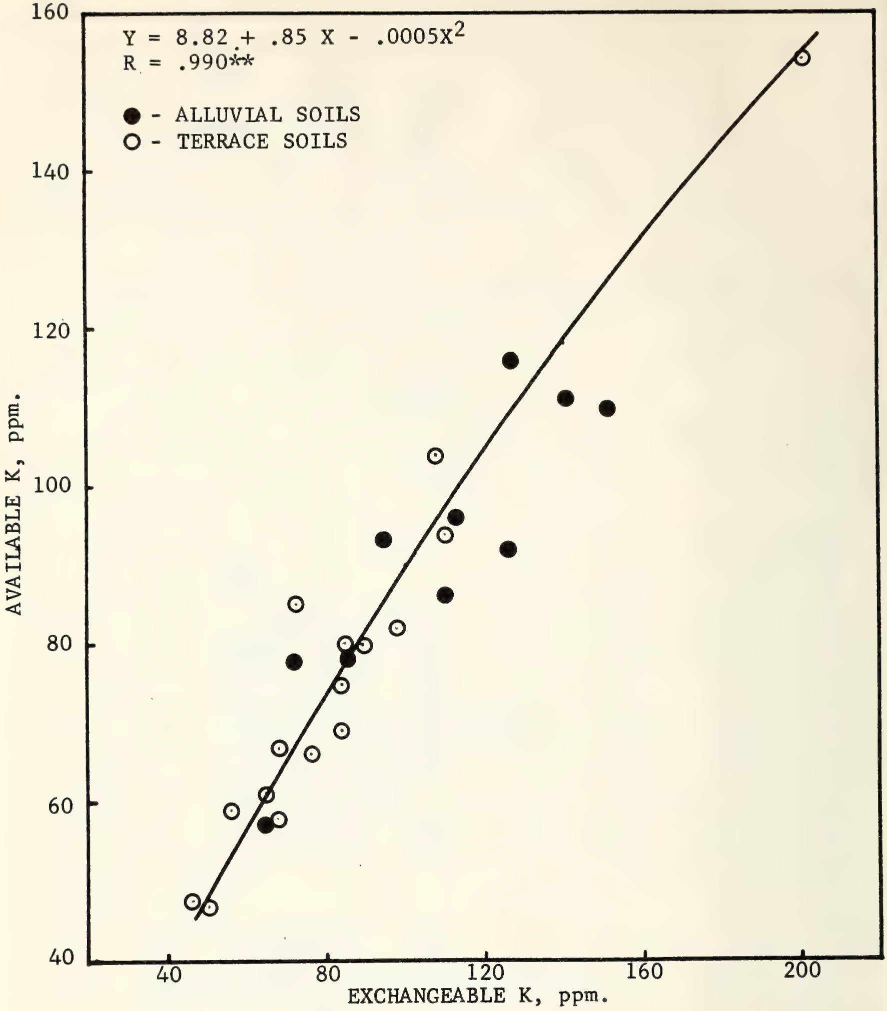

FIGURE 1.—Relationship between exchangeable K and available K extracted with 0.1N HCl at 1:20 soil to solution ratio.

soils. Neidig and McDole (*49*) concluded that total analysis of soils for potassium was of little practical value is estimating crop yield.

Percentage potassium saturation varied from 1.1 to 2.9 per cent, with an average of 1.9 per cent for the Alluvial soils and from 0.5 to 2.2 per cent with an average of 1.3 per cent for the Older Alluvial or Terrace soils. A nonsignificant correlation was obtained between percentage potassium saturation and total potassium. A significant positive correlation (.593) was obtained between percentage potassium saturation and exchangeable potassium.

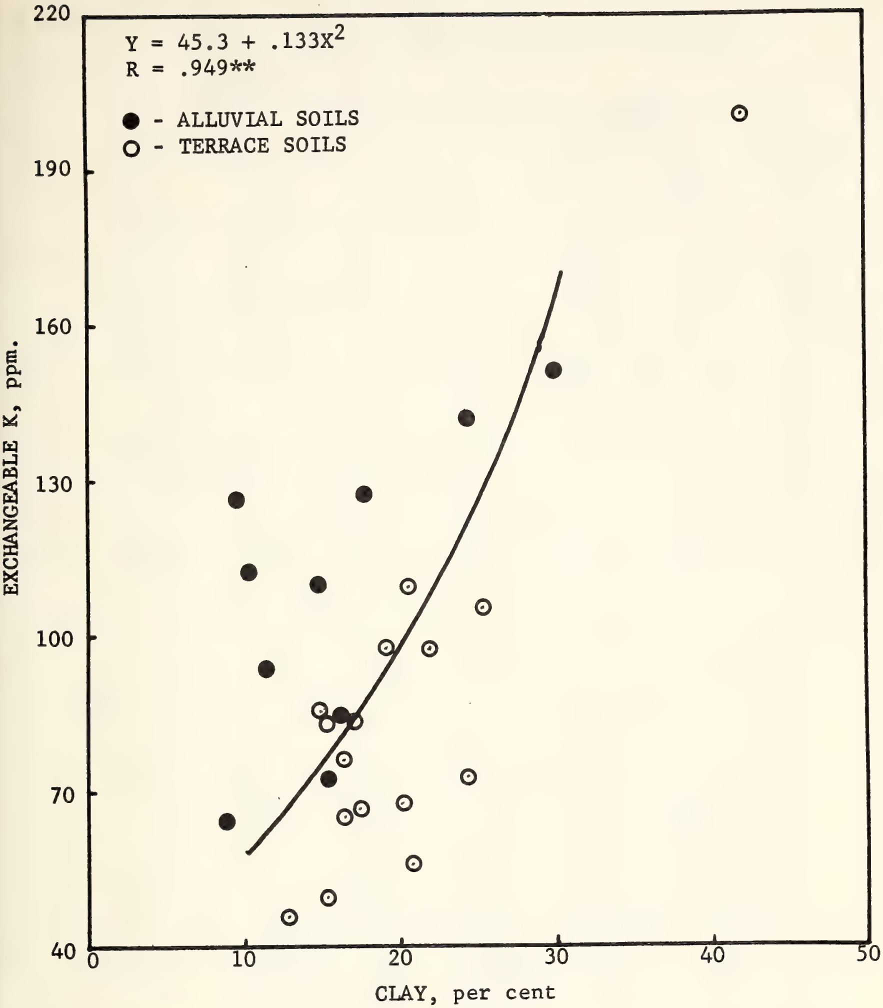

FIGURE 2.—Relationship between exchangeable K and clay contents of the soils.

Calcium Content of the Soils

Data on calcium content of the soils are shown in Table 3. Available calcium extracted with 0.1 N hydrochloric acid and with 1.0 N ammonium acetate was slightly higher at the 1:20 than at the 1:10 soil to solution ratio. The ammonium acetate solution extracted slightly less than the hydrochloric acid solution at either ratio. Available calcium extracted by the methods used was higher in the Alluvial soils than in the Older Alluvial or Terrace soils. Available calcium extracted with 0.1 N hydrochloric acid at 1:20 ratio varied from 1,174 ppm. in Commerce silt loam to 5,085 ppm. in Sharkey clay with an

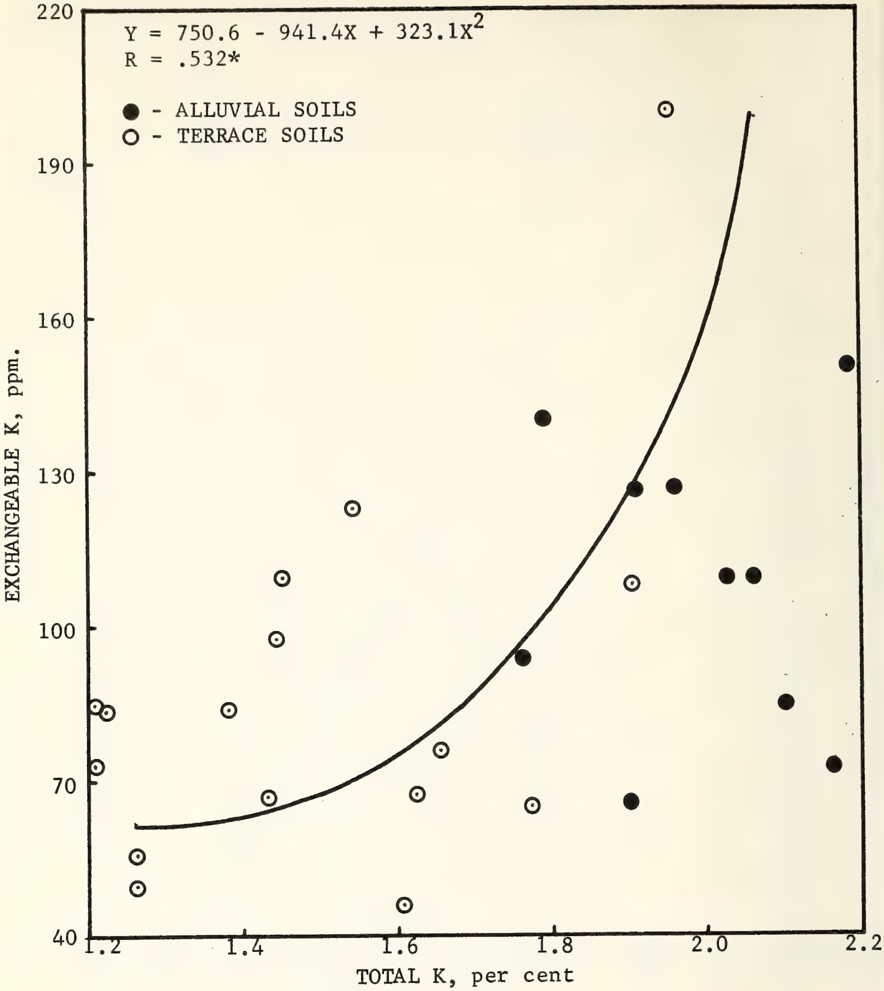

FIGURE 3.—Relationship between exchangeable K and total K contents of the soils.

average of 2,672 ppm. for the Alluvial soils. Available calcium varied from 284 ppm. in Richland silt loam to 10,420 ppm. in Iberia silt loam with an average of 2,408 ppm. for the Older Alluvial or Terrace soils.

Exchangeable calcium varied from 1,261 to 6,740 ppm. with an average of 2,769 ppm. in the Alluvial soils and from 547 to 6,044 ppm. with an average of 2,212 ppm. in the Older Alluvial or Terrace soils. Highly significant correlation coefficients (Table 7) were obtained between exchangeable calcium and available calcium extracted by the different methods. A positive correlation (.559) was obtained between exchangeable calcium and exchangeable potassium. In certain soils, particularly in the Iberia and Yahola series, low amounts of exchangeable

TABLE 3.—Calcium Content of Alluvial Soils and Older Alluvial or Terrace Soils by Various Methods of Extraction

Exp. Loc. No.	Available Soil Ca				Exchangeable Ca		Ca Saturation
	0.1 N HCl		1.0 N NH_4OAc				
	1:10	1:20	1:10	1:20			
	ppm.	ppm.	ppm.	ppm.	ppm.	me./ 100 g.	%
1	3,971	4,615	2,568	3,157	3,329	16.65	85.5
2	1,177	1,297	1,218	1,311	1,383	6.92	60.0
3	1,934	2,103	1,764	2,089	2,042	10.21	63.4
4	1,176	1,174	1,191	1,290	1,308	6.54	56.4
5	2,103	2,083	1,879	2,450	2,205	11.03	61.6
6	1,907	1,993	1,797	1,995	2,021	10.11	60.7
7	2,147	2,229	2,250	2,601	2,518	12.59	58.7
8	1,190	1,378	1,129	1,289	1,261	6.31	65.9
9	1,785	1,979	1,906	2,087	2,193	10.97	65.2
10	3,248	3,444	3,279	3,556	3,641	18.21	65.2
11	3,707	3,959	4,170	4,254	4,591	22.96	65.3
12	5,747	5,805	5,741	6,173	6,740	33.70	66.2
13	685	771	912	1,045	1,015	5.08	45.4
14	1,709	1,732	1,702	1,832	1,972	9.86	58.2
15	2,871	3,228	2,675	2,781	3,073	15.37	76.0
16	1,039	1,469	1,961	2,165	2,276	11.38	39.4
17	3,801	3,930	3,254	3,471	3,764	18.82	68.0
18	2,866	2,949	2,413	2,784	2,722	13.61	61.7
19	5,562	6,625	4,023	4,932	5,222	26.11	81.6
20	2,046	2,369	2,103	2,160	2,352	11.76	65.9
21	2,335	2,543	2,238	2,514	2,711	13.56	63.0
22	9,129	10,420	5,247	6,334	6,044	30.22	83.2
23	365	406	588	670	730	3.65	34.6
24	294	477	487	589	547	2.74	30.1
25	305	325	609	670	731	3.66	26.0
26	284	284	589	670	691	3.46	27.4
27	416	496	622	675	751	3.75	32.6
28	437	497	663	728	794	3.97	32.4

potassium occurred with high amounts of exchangeable calcium. The field results with the Iberia and Jeanerette soils show responses to fertilizer potassium *(70)*. Response of sugar cane to fertilizer potassium on Olivier and Richland soils can be expected due to low amounts of exchangeable potassium in these soils. Response to fertilizer potassium on Jeanerette and Iberia soils can be expected due to low amounts of exchangeable potassium and high amounts of exchangeable calcium which may interfere with the absorption of potassium.

Percentage calcium saturation varied from 56.4 to 85.5 per cent with an average of 64.5 per cent in the Alluvial soils and from 26.0 to 83.2 per cent with an average of 51.6 per cent in the Older Alluvial or Terrace soils.

Magnesium Content of the Soils

Data on magnesium content of the soils are shown in Table 4. Available magnesium extracted with 0.1 N hydrochloric acid and with 1.0 N

TABLE 4.—Magnesium Content of Alluvial Soils and Older Alluvial or Terrace Soils by Various Methods of Extraction

Exp. Loc. No.	Available Soil Mg				Exchangeable Mg		Mg Saturation
	0.1 N HCl		1.0 N NH_4OAc				
	1:10	1:20	1:10	1:20			
	ppm.	ppm.	ppm.	ppm.	ppm.	me./ 100 g.	%
1	896	947	275	296	308	2.52	12.9
2	316	430	307	316	324	2.65	23.0
3	515	686	492	521	562	4.60	28.6
4	265	331	266	270	274	2.24	19.3
5	511	584	480	511	490	4.02	22.4
6	476	549	427	498	492	4.03	24.2
7	733	733	590	650	578	3.74	17.4
8	346	507	211	316	308	2.52	26.3
9	571	718	477	520	526	4.31	25.7
10	895	999	790	854	872	7.15	25.6
11	948	1,205	893	990	842	6.90	19.6
12	1,393	1,565	1,314	1,329	1,546	12.67	24.9
13	274	281	255	262	256	2.10	18.8
14	446	537	409	430	456	3.73	22.4
15	478	598	455	470	492	4.03	19.9
16	750	738	693	745	754	6.18	21.4
17	814	967	783	824	848	6.95	25.1
18	837	1,089	732	792	696	5.71	25.9
19	762	820	613	639	670	5.49	17.2
20	478	535	416	535	492	4.03	22.6
21	518	534	495	524	530	4.34	20.2
22	1,019	1,031	684	712	708	5.81	16.0
23	254	278	254	254	269	2.20	20.9
24	317	353	243	296	291	2.39	26.2
25	139	183	152	183	164	1.34	9.5
26	188	183	188	207	191	1.57	12.5
27	239	234	179	189	203	1.67	14.5
28	177	169	119	169	151	1.23	10.1

ammonium acetate was slightly higher at the 1:20 than at the 1:10 soil to solution ratio. The ammonium acetate solution extracted less magnesium than the hydrochloric acid solution at either ratio. Available magnesium extracted with 0.1 N hydrochloric acid at 1:20 ratio varied from 331 ppm. in Commerce silt loam to 1,565 ppm. in Sharkey clay with an average of 771 ppm. for the Alluvial soils. Available magnesium varied from 169 ppm. in Olivier silt loam to 1,089 ppm. in Jeanerette silt loam with an average of 533 ppm. in the Older Alluvial or Terrace soils.

Exchangeable magnesium varied from 274 to 1,546 ppm. with an average of 594 ppm. in the Alluvial soils and from 151 to 848 ppm. with an average of 448 ppm. for the Older Alluvial or Terrace soils. Highly significant correlation coefficients (Table 7) were obtained between exchangeable magnesium and available magnesium extracted by the different methods. The Alluvial soils generally contained more exchangeable and available magnesium than the Older Alluvial or Terrace soils.

Percentage magnesium saturation varied from 12.9 to 28.6 per cent with an average of 22.5 per cent for the Alluvial soils and from 9.5 to 26.2 per cent with an average of 19.0 per cent for the Older Alluvial or Terrace soils. Correlation coefficients shown in Table 7 indicate that the potassium content of the soils studied was more closely related to the magnesium than the calcium content. However, this was not the case in the Jeanerette and Iberia soils.

Cation Exchange Capacity of the Soils

Cation exchange capacity, exchangeable hydrogen content and pH values of the soils are presented in Table 5. Cation exchange capacity in the Alluvial soils varied from 9.58 to 50.89 with an average of 21.26 me. per 100 grams of dry soil. Cation exchange capacity in the Older Alluvial or Terrace soils varied from 9.09 to 36.32 with an average of 19.05 me. per 100 grams of dry soil. Driskell (*18*) found that the average cation exchange capacity of five major soil types of the Older Alluvial or Terrace soils was 17.3 me. per 100 grams of soil. Wyatt and Patrick (*77*) reported that the cation exchange capacity of Cypremort, Baldwin and Iberia soils was 11.9, 19.0 and 22.8 me. per 100 grams, respectively.

Base saturation in the Alluvial soils was composed of 1.9 per cent potassium, 64.5 per cent calcium, 22.5 per cent magnesium and 0.9 per cent sodium, or a total of 89.8 per cent. Base saturation in the Older Alluvial or Terrace soils was composed of 1.3 per cent potassium, 51.6 per cent calcium, 19.0 per cent magnesium, 1.2 per cent sodium, a total of 73.0 per cent. Correlation coefficients in Table 7 show that the exchangeable potassium was closely associated with the cation exchange capacity, but the total potassium was not associated with the cation exchange capacity.

In the Alluvial soils, pH varied from 5.6 in Commerce silt loam to

TABLE 5.—Exchange Properties in Milli-Equivalents per 100 Grams of Dry Soil and pH Values of Alluvial Soils and Older Alluvial or Terrace Soils

Exp. Loc. No.	Base Exchange Capacity	Exchangeable Hydrogen	Cation Exchange Capacity	Percentage Base Saturation	Soil pH
1	19.48	–	19.48	100.0+	7.3
2	9.98	1.55	11.53	86.6	6.0
3	15.18	0.92	16.10	94.3	6.9
4	9.28	2.32	11.60	80.0	5.6
5	15.62	2.30	17.92	87.2	6.2
6	14.54	2.10	16.64	87.4	5.9
7	16.93	4.52	21.45	78.9	5.7
8	9.11	0.48	9.58	95.0	6.9
9	15.60	1.21	16.81	92.8	6.8
10	25.88	2.04	27.92	92.7	6.4
11	30.88	4.30	35.18	87.8	6.2
12	48.08	2.81	50.89	94.5	6.6
13	7.44	3.75	11.19	66.5	4.9
14	14.00	2.95	16.95	82.6	5.7
15	19.82	0.41	20.23	98.0	7.1
16	18.29	10.59	28.89	63.3	4.8
17	26.60	1.06	27.66	96.2	6.8
18	20.08	1.98	22.06	91.0	7.0
19	31.83	0.18	32.00	99.5	7.2
20	16.13	1.73	17.86	90.3	6.7
21	18.31	3.21	21.53	85.1	5.8
22	36.32	–	36.32	100.0+	7.3
23	6.27	4.27	10.54	59.5	5.2
24	5.49	3.60	9.09	60.4	5.2
25	5.35	8.73	14.08	38.0	5.1
26	5.43	7.18	12.61	43.1	5.0
27	5.77	5.75	11.51	50.1	5.5
28	5.45	6.81	12.25	44.5	5.3

7.3 for Yahola silt loam while in the Older Alluvial and Terrace soils it varied from 4.8 for Baldwin silty clay to 7.3 for Jeanerette silt loam and Iberia silt loam. A wide variation in soil reaction occurred among some of the soil types at different experimental locations. It is apparent that a definite need for liming the soil exists in some areas. The pH varied from 4.9 to 5.5 in the Cypremort, Olivier and Richland soils.

Physical Properties and Available Phosphorus Content of the Soils

Clay, organic matter, total nitrogen, and available phosphorus contents of the soils are presented in Table 6. Wide variations were found in clay content of the Alluvial soils. Shuker (*64*) studied the physical properties of the Cypremort, Baldwin and Iberia series, which are among the Older Alluvial or Terrace soil group. He found that poor internal soil drainage and poor soil structure commonly occur in these soils. It was found that available and exchangeable cations increased significantly with an increase in clay content of the soils.

The organic matter content of the Alluvial soils varied from 0.78 per cent in Mhoon silt loam to 3.66 per cent in Sharkey clay. Organic matter content in the Older Alluvial or Terrace soils varied from 1.18 per cent in Cypremort silt loam to 3.32 per cent in Jeanerette silt loam.

TABLE 6.—Clay, Organic Matter, Total Nitrogen and Available Phosphorus Contents of Alluvial Soils and Older Alluvial or Terrace Soils

Exp. Loc. No.	Soil Type	Clay	Organic Matter	Total N	N in O.M.	Avail.[1] P
		%	%	%	%	ppm.
1	Yahola sil	11.4	1.02	0.041	4.02	241
2	Commerce 1	10.1	1.10	0.067	6.10	330
3	Commerce sil	14.8	1.42	0.067	4.72	299
4	Commerce sil	9.6	1.18	0.064	5.42	237
5	Mhoon 1	17.9	1.24	0.076	6.13	205
6	Mhoon sil	16.1	1.18	0.066	5.59	216
7	Mhoon sil	24.5	1.40	0.086	6.14	181
8	Mhoon sil	8.9	0.78	0.064	8.21	366
9	Mhoon sil	15.3	1.38	0.068	4.93	233
10	Mhoon sicl	29.9	2.07	0.095	4.59	242
11	Mhoon sic	43.4	2.27	0.105	4.63	336
12	Sharkey c	60.5	3.66	0.175	4.78	362
13	Cypremort sil	12.7	1.18	0.062	5.25	33
14	Baldwin sil	16.1	1.80	0.089	4.94	48
15	Baldwin sil	16.1	1.55	0.071	4.58	82
16	Baldwin sic	42.0	2.17	0.125	5.76	30
17	Jeanerette sil	25.2	1.61	0.114	7.08	105
18	Jeanerette sil	21.9	1.58	0.110	6.96	132
19	Jeanerette sil	20.6	3.32	0.131	3.95	451
20	Jeanerette sil	14.8	2.42	0.114	4.71	178
21	Iberia sil	20.0	1.79	0.108	6.03	84
22	Iberia sil	24.1	2.40	0.196	8.17	90
23	Patoutville sil	15.2	1.27	0.078	6.14	15
24	Patoutville sil	15.2	1.27	0.069	5.43	10
25	Richland sil	19.0	2.37	0.115	4.85	27
26	Richland sil	20.3	1.76	0.098	5.57	31
27	Richland sil	16.5	1.38	0.094	6.81	37
28	Olivier sil	17.3	2.12	0.115	5.42	68

[1] Avail. P extracted with 0.1 N HCl + .03 N NH_4F at 1:20 ratio.

A significant positive correlation was obtained between organic matter content and clay content of the soils. Wyatt and Patrick (*77*) obtained a similar relationship between organic matter and clay contents of Cypremort, Baldwin and Iberia soils. The average percentage organic matter for each per cent clay was 0.081 in Alluvial soils and 0.099 in Older Alluvial or Terrace soils. There were, however, some low values in each group. Sturgis (*69*) pointed out that soils must contain as much as 0.08 per cent soil organic matter for each per cent of clay to preserve the physical conditions necessary for crops to efficiently use applied fertilizers. Although the average percentage organic matter for each per cent clay in each soil group was above 0.08, the organic matter content at some of the locations was low and consequently the soils were in poor physical condition.

Total nitrogen content varied from 0.041 to 0.175 per cent in the Alluvial soils and from 0.062 to 0.196 per cent in the Older Alluvial or Terrace soils. The average percentage of total nitrogen in the soil organic matter was 5.44 per cent in the Alluvial soils and 5.73 per cent in the Older Alluvial or Terrace soils. It is noted that the Older Alluvial or Terrace soils were lower in exchangeable bases but higher in organic matter content than the Alluvial soils.

Data on available soil phosphorus are presented in Table 6 to complete the information on the fertility status of soils studied. Byrnside and Sturgis (*11*) made a more complete study of the soil phosphorus as related to response of sugar cane to fertilizer phosphorus.

Response of Sugar Cane to Fertilizer Potassium

Sugar cane yield responses to fertilizer potassium obtained in experiments on the Alluvial soils and Older Alluvial or Terrace soils are presented in Tables 8 and 9, respectively. Yield responses were determined in each experiment by difference between yield on plots with applied potassium and yield of plots without applied potassium at each of the three levels of applied nitrogen and the two levels of applied phosphorus. Since the factorial analysis of the yield data from each experiment revealed that significant interactions among fertilizer treatments occurred in only six experiments at the 5 per cent level, the responses to potassium were recorded as an average of the differences between N and N-K treatments and between N-P and N-P-K treatments at the three levels of N. However, since the interactions were close to significant at the 10 per cent level in 13 of the experiments, the responses were also recorded as determined by a method of comparison. By the comparative method, the yield responses from fertilizer N, P and K in each experiment were carefully examined and the response due to potassium at the N and P levels which appeared to be most representative of the experiment was recorded as the response to potassium. The fertilizer treatment from which the response to potassium was obtained in each experiment is shown in Tables 8 and 9. Although a human error may be involved in the method of comparison, it is felt

TABLE 7.—Simple Correlation Coefficients Showing the Relationships Between Some of the Chemical and Physical Properties of the Soils Studied

Variable	% O.M.	% Clay	Total K	Exch. K	Exch. Ca	Exch. Mg
Percentage Clay	.702	–	.301	.873	.651	.843
Exchangeable K	.555	.873	.459	–	.559	.769
% K Saturation	–.051	.272	.369	.593	–.202	.044
Avail. K; HCl @ 1:10	.493	.873	.475	.948	–	–
Avail. K; HCl @ 1:20	.529	.893	.480	.975	.595	.776
Avail. K; NH_4OAc @ 1:10	.549	.903	.441	.984	–	–
Avail. K; NH_4OAc @ 1:20	.546	.901	.441	.987	.540	.747
Avail. Ca; HCl @ 1:20	.530	.395	–.022	.275	.925	.630
Avail. Mg; HCl @ 1:20	.472	.704	.408	.642	.895	.908
Cation Exchange Capacity	.763	.858	.238	.722	.944	.921
% Base Saturation	.032	.058	.398	.106	.661	.531

Least significant r at the 1% level = .478.
Least significant r at the 5% level = .374

that the responses determined by this method with experiments in which interactions occurred are of more practical value than by the factorial method in which only average responses are considered and the interaction effects are ignored.

Yield responses to fertilizer potassium as determined by the factorial method were positive in all experiments on Alluvial soils. A maximum response to fertilizer potassium of 1.9 tons per acre with a yield increase of 9.2 per cent was obtained on Commerce loam at Smithfield Plantation with stubble cane. Average responses for all locations on Alluvial soils with plant and stubble cane were 0.7 and 0.9 tons per acre, respectively. Positive responses to fertilizer potassium were obtained in all except two experiments on Older Alluvial or Terrace soils. A maximum response of 3.3 tons per acre with a yield increase of 16.7 per cent was obtained on Richland silt loam at Young's Industries, Inc., with stubble cane. Average responses for all locations on Older Alluvial or Terrace soils with plant and stubble cane were 0.7 and 2.2 tons per acre, respectively. Holmes (*30*) obtained similar results which indicated that the deficiency of potassium was greater in the Older Alluvial or Terrace soils along Bayou Teche than in the Alluvial soils along the Mississippi River and Bayou Lafourche. This is partially due to the fact that older soils are more weathered.

The relationship between available soil potassium extracted with 0.1 N HCl at the 1:20 ratio and response of plant and stubble cane to fertilizer potassium as determined by the factorial method was evaluated. A regression equation with a nonsignificant coefficient was obtained for this relationship.

Yield responses to fertilizer potassium as determined by the comparative method were positive in all experiments on Alluvial soils. A maximum response of 3.3 tons per acre, a yield increase of 13.9 per cent, was obtained on Mhoon loam at Smithfield Plantation with first stubble

TABLE 8.–Sugar Cane Yield Responses due to Fertilizer Potassium on Alluvial Soils by the Factorial and Comparative Methods of Analysis

					Factorial Method		Comparative Method				
Exp. Loc. No.	Soil Type	Avail. Soil K	Age of Cane	Yield without Fert.	Yield without K_2O	Resp. to K_2O	Treat. without K_2O	Yield without K_2O	Treat. with K_2O	Yield with K_2O	Resp. to K_2O
		ppm.		T/A.	T/A.	T/A.	N-P_2O_5-K_2O Lbs./A.	T/A.	N-P_2O_5-K_2O Lbs./A.	T/A.	T/A.
1	Yahola sil	93	Pl.	24.2	24.4	1.1	80–40–0	24.3	80–40–60	26.8	2.5
2	Commerce 1	96	Pl.	25.3	31.8	0.8	60–0–0	31.7	60–0–60	33.3	1.6
2	Commerce 1	96	St.	13.6	20.6	1.9*	100–0–0	20.6	100–0–60	22.7	2.1*
3	Commerce sil	86	Pl.	25.1	28.5	0.0	60–40–0	27.1	60–40–60	28.3	1.2
3	Commerce sil	86	St.	20.6	24.6	0.8	80–0–0	22.7	80–0–60	24.7	2.0
4	Commerce sil	92	Pl.	28.0	27.8	1.1	80–40–0	27.0	80–40–80	28.2	1.2
4	Commerce sil	92	St.	24.8	28.2	1.6*	120–0–0	29.6	120–0–80	31.0	1.4
5	Mhoon 1	117	Pl.	20.4	28.5	1.1	60–0–0	28.1	60–0–60	28.5	0.4
5	Mhoon 1	117	St.	21.4	27.3	0.2	100–0–0	28.0	100–0–60	28.7	0.7
5	Mhoon 1	117	St.	12.1	19.1	0.7	100–0–0	20.4	100–0–60	21.3	0.9
6	Mhoon sil	78	St.	16.9	26.7	1.4*	80–40–0	26.6	80–40–60	28.0	1.4
6	Mhoon sil	78	St.	14.4	21.6	0.7	80–40–0	22.7	80–40–60	23.6	0.9
7	Mhoon sil	111	St.	36.8	42.0	0.5	160–40–0	44.7	160–40–80	44.7	0.0
8	Mhoon 1	57	St.	18.7	24.8	0.7	120–40–0	23.8	120–40–60	27.1	3.3
9	Mhoon 1	78	Pl.	28.5	33.5	0.9*	80–0–0	32.9	80–0–80	35.5	2.6*
9	Mhoon 1	78	St.	25.6	32.4	1.6	160–0–0	32.0	160–0–80	34.9	2.9*
9	Mhoon 1	78	St.	14.7	18.7	0.3	120–0–0	17.1	120–0–80	19.0	1.9
10	Mhoon sicl	110	St.	22.8	31.8	0.7	120–40–0	32.0	120–40–80	32.9	0.9
10	Mhoon sicl	110	St.	21.3	27.5	0.4	160–40–0	28.2	120–40–80	29.7	1.5
11	Mhoon sic	227	St.	29.3	37.6	1.1	160–40–0	40.7	160–40–80	41.3	0.6
12	Sharkey c	311	Pl.	21.2	22.3	0.1	120–0–0	22.6	120–0–80	22.8	0.2
12	Sharkey c	311	St.	24.4	29.9	0.7	160–0–0	30.6	160–0–80	30.9	0.3
Average for Alluvial Soils			Pl.	24.7	29.8	0.7		27.7		29.1	1.4
Average for Alluvial Soils			St.	21.2	25.4	0.9		28.0		29.4	1.4

*Significant at 5% level of probability.

Pl. = Plant cane; St. = Stubble cane.

Exp. Loc. No.	Soil Type	Avail. Soil K	Age of Cane	Yield without Fert.	Factorial Method		Comparative Method				
					Yield without K_2O	Resp. to K_2O	Treat. without K_2O	Yield without K_2O	Treat. with K_2O	Yield with K_2O	Resp. to K_2O
		ppm.		T/A.	T/A.	T/A.	$N-P_2O_5-K_2O$ Lbs./A.	T/A.	$N-P_2O_5-K_2O$ Lbs./A.	T/A.	T/A.
13	Cypremort sil	47	St.	27.9	31.2	2.0*	160–0–0	31.8	160–0–80	35.0	3.2
14	Baldwin sil	61	Pl.	25.3	28.3	1.3	60–0–0	27.5	60–0–60	29.6	2.1
14	Baldwin sil	61	St.	20.3	26.7	3.2*	120–0–0	27.7	120–0–60	30.7	3.0
14	Baldwin sil	61	St.	17.6	21.7	2.5	120–0–0	21.3	120–0–60	23.8	2.5
15	Baldwin sil	66	Pl.	35.8	38.3	–0.4	120–40–0	38.4	120–40–80	39.8	1.4
15	Baldwin sil	66	St.	27.3	37.9	0.0	160–40–0	38.2	160–40–80	40.8	2.6
16	Baldwin sic	155	Pl.	15.8	20.8	1.0	40–0–0	19.8	40–0–60	20.1	0.3
16	Baldwin sic	155	St.	17.6	27.7	2.4*	120–40–0	30.3	120–40–60	30.2	–0.1
16	Baldwin sic	155	St.	11.3	16.7	1.9*	80–40–0	17.8	80–40–60	18.9	1.1
17	Jeanerette sil	104	Pl.	27.4	31.9	0.7	80–0–0	31.7	80–0–60	32.6	0.9
17	Jeanerette sil	104	St.	22.0	27.7	2.1*	100–0–0	28.8	100–0–60	29.4	0.6
18	Jeanerette sil	80	Pl.	37.3	38.4	–0.8	120–0–0	36.9	120–0–80	38.5	1.6
19	Jeanerette sil	59	St.	23.9	25.2	2.2*	160–40–0	24.9	160–40–80	27.7	2.8
20	Jeanerette sil	80	Pl.	22.3	21.7	1.1	40–40–0	21.1	40–40–80	21.9	0.8
20	Jeanerette sil	80	St.	21.9	30.4	2.1*	120–40–0	29.7	120–40–80	32.1	2.4
21	Iberia sil	67	Pl.	18.5	22.9	0.1	40–0–0	21.8	40–0–60	22.5	0.7
21	Iberia sil	67	St.	14.9	19.4	2.1*	100–0–0	19.0	100–0–60	20.3	1.3
22	Iberia sil	85	Pl.	22.7	25.9	0.9	80–0–0	25.6	80–0–60	27.7	2.1
23	Patoutville sil	75	Pl.	18.0	22.6	1.2	80–0–0	24.0	80–0–60	26.3	2.3
24	Patoutville sil	47	Pl.	18.1	23.1	0.8*	60–0–0	23.0	60–0–60	25.4	2.4*
25	Richland sil	82	Pl.	18.9	22.9	2.2	60–0–0	24.0	60–0–60	25.9	1.9*
25	Richland sil	82	St.	12.3	19.6	3.3	80–0–0	16.4	80–0–60	17.9	1.5
26	Richland sil	94	Pl.	15.2	18.0	0.6	40–0–0	16.3	40–0–60	17.0	0.7*
27	Richland sil	69	St.	17.6	21.6	1.4	100–0–0	20.3	100–0–60	22.9	2.6*
28	Olivier sil	58	Pl.	25.0	26.6	0.8	40–40–0	25.7	40–40–60	27.6	1.9
28	Olivier sil	58	St.	19.0	21.4	1.5*	100–40–0	20.2	100–40–60	23.8	3.6*
28	Olivier sil	58	St.	22.0	24.3	2.9	80–40–0	25.0	80–40–80	28.8	3.8
Average for Terrace Soils			Pl.	23.1	26.3	0.7		25.8		27.3	1.5
Average for Terrace Soils			St.	19.7	23.6	2.2		25.1		27.3	2.2

*Significant at 5% level of probability.
Pl. = Plant cane;   St. = Stubble cane.

cane. Average response for all locations on Alluvial soils with plant and stubble cane was 1.4 tons per acre. Yield responses to fertilizer potassium were positive in all except one experiment on Older Alluvial or Terrace soils. A maximum response of 3.8 tons per acre with a yield increase of 15.2 per cent was obtained on Olivier silt loam at Young's Industries, Inc., in Lafayette Parish. Average responses for all locations on Older Alluvial or Terrace soils with plant and stubble cane were 1.5 and 2.2 tons per acre, respectively.

The relationship between available soil potassium extracted with 0.1 N HCl at 1:20 ratio and response of plant and stubble sugar cane to fertilizer potassium as determined by the comparative method was evaluated. A significant regression equation with a coefficient of .620 was obtained for this relationship.

Since the average response is probably more reliable in experiments with no interactions, the relationship between available potassium and response to potassium was evaluated, using the average responses from the factorial analysis in experiments with no interaction and responses from the comparative analysis in experiments with interactions. The significant regression equation ($R = .698$) shown in Figure 4 was obtained for this relationship. The regression curve shows that a profitable response of more than one ton per acre was obtained on soils which contained less than 110 ppm. of available potassium. This is in accordance with previous work in Louisiana. Sturgis and Byrnside (70) reported in a summary of 10 years work that more than 50 per cent of the soils tested in the sugar cane area were low in exchangeable potassium and that response to fertilizer potassium could be expected if the ex-

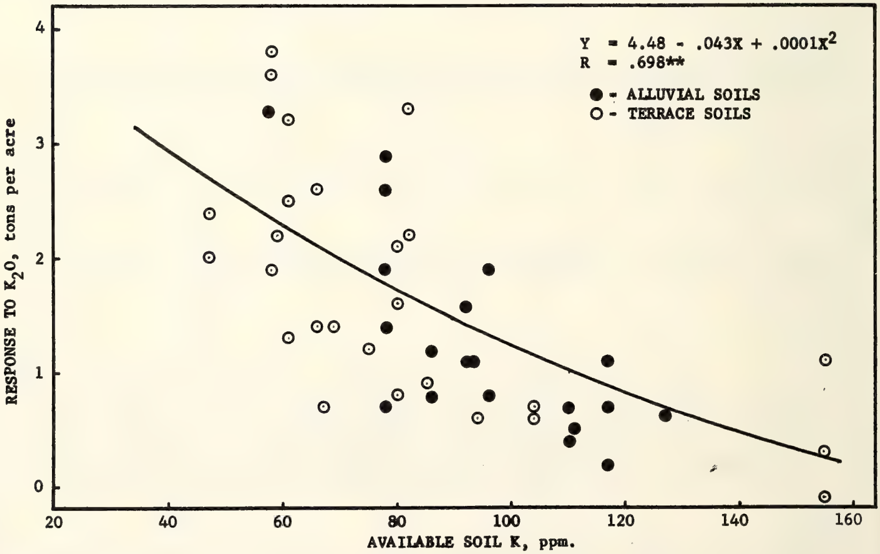

FIGURE 4.—Relationship between response of sugar cane to 60-80 pounds of K_2O and available soil K extracted with 0.1N HCl at a 1:20 soil to solution ratio.

changeable potassium is below 110-160 ppm. (*12*). Holmes (*29*) in 1937 found a high negative correlation between soil potassium extracted with 0.05 N HCl at 1:10 ratio and response of sugar cane to fertilizer potassium. He obtained responses where the extractable potassium was less than 260 ppm. This responsive level of potassium is considerably higher than levels set in more recent studies. Humbert (*32*) in Hawaii found that the critical level of exchangeable soil potassium for sugar cane was 75 ppm. Ayres and Hagihara (*4*) obtained no yield increase due to fertilizer potassium where the soil contained more than 100 ppm. of potassium.

The response of sugar cane to fertilizer potassium was measured 244 times at the various levels of applied nitrogen and phosphorus in the 49 experiments conducted. The distribution of the number of response measurements at different ranges of response is shown in Figure 5. This shows that 66.3 per cent of the responses averaged one ton or more per acre and 15.5 per cent of the responses were negative. The negative responses were probably due to unbalanced combinations of nitrogen, phosphorus and potassium or to experimental error. Therefore, profitable responses to fertilizer potassium were obtained approximately two-thirds of the time. This is a basis for the current general recommendation of 80 pounds of K_2O per acre for sugar cane in Louisiana. The recommendation is in close agreement with those in other sugar cane producing areas. According to Halliday (*24*) the present world-wide recommendation of fertilizer potassium for sugar cane at the medium level of available soil potassium of 100 to 120 ppm. is 82 pounds of K_2O per acre.

Uptake of Potassium by Sugar Cane

Data on the uptake of potassium were obtained from six of the fertilizer experiments and were reported in the Louisiana Agricultural Experiment Station Bulletin No. 574. It was found that the average amount of potassium in the entire growth, including roots, was 6.74 pounds expressed as K_2O per ton of millable cane. The amount varied from 4.47 pounds on Cypremort silt loam to 9.20 pounds on Baldwin silty clay loam. Approximately 3.5 pounds of K_2O left the field in the cane and trash per ton of millable cane.

Results show that a highly positive correlation exists between the potassium content of sugar cane and available soil potassium and applied fertilizer potassium. This is evidence that the 0.1 HCl solution is a reliable extractant for available soil potassium.

Rainfall and Yield of Sugar Cane

Rainfall was measured at each experimental location. Simple correlation coefficients were calculated between rainfall during different periods of the year and yield of sugar cane from several fertilizer treatments at each location. Correlations were also calculated between rainfall and response of sugar cane to fertilizer potassium.

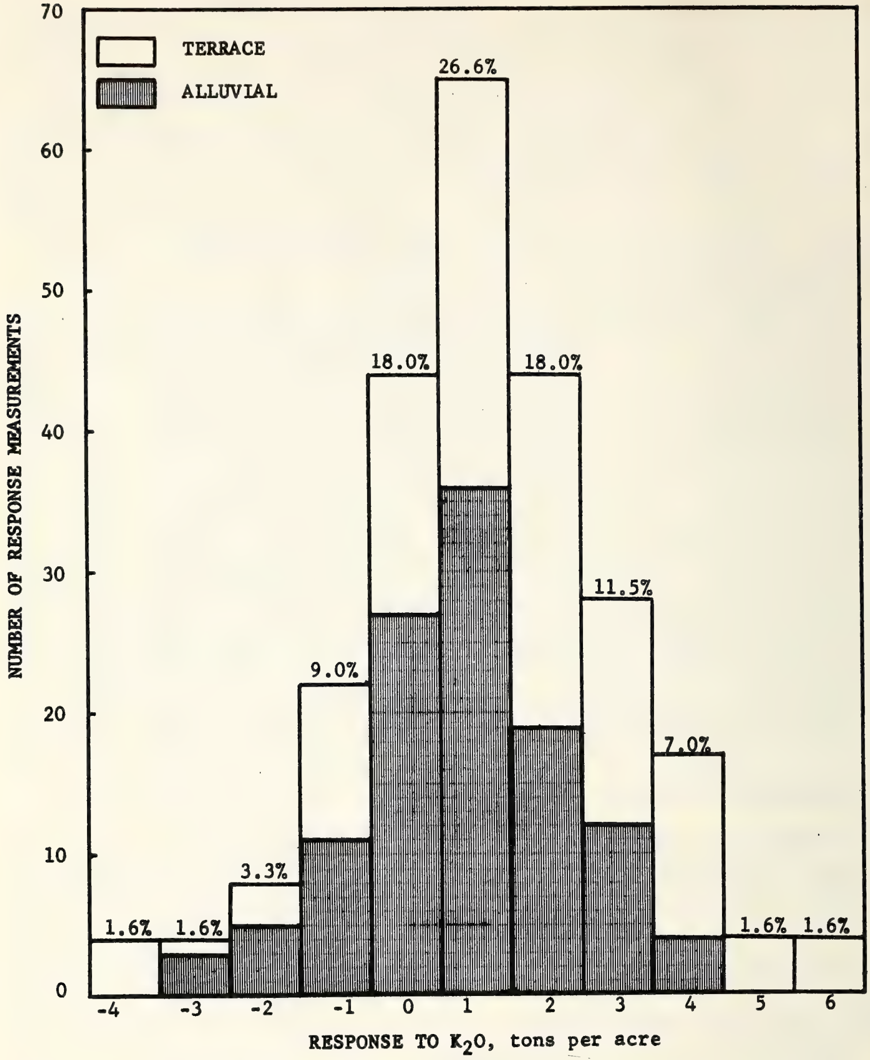

FIGURE 5.—Distribution of yield responses of sugar cane to 60-80 pounds of K_2O.

Although several of the correlations were statistically significant, only a few were considered highly important. A majority of the correlation values showed a negative association between yield of sugar cane and rainfall for certain months. It was apparent that excessive rainfall during the spring of the year could cause a reduction in yield. It is very probable that better cultivation, weed control and fertilization practices and better soil aeration are factors responsible for greater yields during a year with a relatively drier spring season.

General Discussion

Several important observations were made during the course of this study.

Soils within the Alluvial group and soils within the Older Alluvial or Terrace group vary widely in their properties. It would be desirable to study the individual soil types within each group as well as by groups. This is particularly true for the Older Alluvial or Terrace soils. The Richland and Olivier soils are older, shallower, and more depleted of nutrient elements than the Baldwin, Jeanerette and Iberia soils. There is also considerable variation within a soil series, i.e. available potassium in Baldwin soils.

The depth of the feeding zone in the soil should be considered in the determination of available nutrients by chemical methods. Shallow soils usually respond to applied potassium at higher soil test values than relatively deep soils, such as the Yahola soils, which respond only at lower test values. Also, since some of the plant roots feed in the subsoil, the contribution of the subsoil to the growth of plants should be considered. Humbert *(34)* pointed out that the volume weight of a soil should be considered when critical levels of soil nutrients are established.

Although the amount of potassium removed by a crop is small relative to the total amount in the soil, a minimum level of available potassium should be maintained to produce normal plant growth. On the other hand, the maintenance of a very high level of available potassium in the soil is not only a needless expense but, as Clements *(14)* pointed out, it can cause difficulty in the crystallization of sugar.

The amount and distribution of precipitation have a well-known influence on the yield of crops. This influence is partially due to effect of the soil moisture on the availability of soil and fertilizer nutrient elements to plants. It is probable that during dry seasons the availability of soil nutrients decreases and the yield response to applied fertilizer increases. Worsham *(76)* found that increasing soil moisture to saturation increased the available potassium.

It is apparent from this study that the response of sugar cane to fertilizer potassium varied widely and was not very highly associated with the total soil potassium. This was due in part to several factors, such as the nature of the soil, depth of the soil, requirements of the crop, precipitation and other factors. It was also due in part to the conditions under which the experiments were conducted. These experiments were conducted on privately-owned plantations which naturally necessitated that the experiments conform to plantation practices. These practices were not always highly conducive to good experimentation. In order to have more precise measurement of yield and calibration of soil testing methods with yield, it will be necessary in the future to conduct more fertilizer experiments with sugar cane under better controlled conditions.

The response to fertilizer potassium was positive in most experiments conducted and in several cases statistically significant. The available potassium content of several soil series and some soil types within other series was at a responsive level below 110 ppm. As the yield of sugar cane increases, the potassium content of more soils will be at a responsive level and consequently the usage of fertilizer potassium will increase. It is conceivable that within the next 10 years, most of the sugar cane growers will be applying recommended rates of fertilizer potassium to all except clay soils.

Summary and Conclusions

A study was made of the total soil potassium, exchangeable cations, and other soil properties as related to yield and response of sugar cane to fertilizer potassium. Forty-nine fertilizer experiments were conducted at 28 locations on 16 soil types of the Alluvial soils and Older Alluvial or Terrace soils from 1954 to 1963.

A normal ammonium acetate solution extracted more potassium from the soils than a 0.1 N hydrochloric acid solution. This was particularly true for soils relatively high in clay content. More soil cations were extracted at a 1:20 than at a 1:10 soil to solution ratio with either extractant. Potassium extracted by the methods studied was generally higher in the Alluvial soils than in the Older Alluvial or Terrace soils. Although the available or 0.1-N-hydrochloric-acid-extractable potassium was slightly lower in amount, it was highly associated with the exchangeable potassium. Available potassium was not highly associated with total soil potassium, but it was highly correlated with clay content and to a lesser degree with organic matter content of the soil. The per cent of organic matter for each per cent clay was on an average .085 in the Alluvial soils and .098 in the Older Alluvial or Terrace soils.

Results from an analysis of the yield data of sugar cane revealed that the maximum yield response obtained to fertilizer potassium was 3.3 tons per acre on the alluvial soils and 3.8 tons per acre on the Older Alluvial or Terrace soils. In all except three experiments, the responses to potassium were positive and in several experiments the responses were statistically significant.

The negative relationship between available soil potassium and response of sugar cane to fertilizer potassium was highly significant. The regression equation for this relationship shows that a profitable response of more than one ton per acre was obtained on soils which contained less than 110 ppm. of available potassium. Generally, greater responses to applied potassium were obtained with stubble cane than with plant cane, especially on the Older Alluvial or Terrace soils.

Results show that approximately two-thirds of the yield responses obtained from fertilizer potassium were profitable where the general recommendation of 80 pounds of K_2O was applied. Most of the profitable responses were obtained where the soil contained less than 110 ppm. of available potassium.

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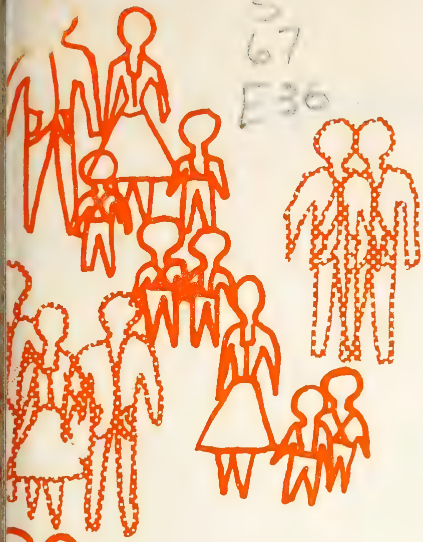

louisiana's human resources

Part IV

Migration of Working Aged Population

Roger L. Burford
in consultation with
Alvin L. Bertrand and
Walfrid J. Jokinen

DEPARTMENT OF RURAL SOCIOLOGY
LOUISIANA STATE UNIVERSITY AND
AGRICULTURAL AND MECHANICAL COLLEGE
AGRICULTURAL EXPERIMENT STATION
DOYLE CHAMBERS, DIRECTOR

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Louisiana's Human Resources

Part IV

Migration of Working Aged Population

ROGER L. BURFORD*
in consultation with
ALVIN L. BERTRAND AND WALFRID J. JOKINEN**

The readiness of people to migrate from one place of residence to another has become one of the most striking features of our modern world, particularly in this country. The mobility of the American people is much greater now than before World War II. This greatly increased mobility is no doubt the result of many factors, but probably stems mainly from only a few, such as improved economic conditions nationally, improved means of transportation, and greater knowledge of opportunities and living conditions in other areas than was previously the case.

Migration has many causes and many consequences. Some of these are economic in nature and others are sociological. The objectives of this study are to present data on the migration patterns of working aged population in Louisiana, and to discuss these in relation to some of the generally accepted economic causes of migration as well as some of its economic consequences. First, there will be a rather general discussion of the economic significance of migration, followed by a slightly technical discussion of definitions and methods of measuring migration. This will be followed by a presentation and discussion of data on specific patterns of migration within Louisiana. Here, there will be a more specific and detailed discussion of the causes and especially the likely consequences of these patterns for Louisiana's economic future.

The Economic Significance of Migration

The process of migration has economic significance in the relatively short run mainly in that it provides the most important avenue by which the supply of labor in a given labor market may be adjusted to the existing demand. Over a somewhat longer span of time it has further economic significance in that the process of migration itself modifies not only the supply of labor in a given market, but the demand for labor as well. That is to say, areas having substantial gains in population as a result of migratory inflows generally represent expanding markets for firms seeking new outlets. This may lead to the movement of business to, or the expansion of business in, those areas. At the same time, areas having little or no gains in population (and especially those having losses) are generally looked upon less favorably for new business expansion.[1] Extending the argument still further, such new business expansion as may result from growth of population in turn would generally result in further increases in demand for labor in the area, and hence still more inmigration.

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*Asso. Prof., Dept of Business Finance and Statistics.

**Prof. and Head of Dept. of Rural Sociology, respectively.

Thus, the process of migration tends to be cumulative. First, it results primarily from real or imagined differences in economic opportunities in various areas. If the differences are real, the shifts in population resulting from the migration tend to create still further differences in opportunities.[2] The areas gaining population represent expanding markets, while those losing population are generally areas of static or declining markets. These new differences in opportunities lead to still more migration, and so on.

Migration, moreover, has significance in providing an index or measure of the relative abundance of economic opportunities (or demand for labor relative to supply) in any two or more areas at a point in time, or changes through time. Perhaps the most important single factor explaining an area's migration pattern is the state of its relative economic opportunities. It has long been recognized that migratory flows are generally from areas of relatively poor economic opportunities to those having opportunities in relatively greater abundance.[3] Poor opportunities tend to exert an expulsive force on the population in an area, while better opportunities elsewhere represent something of a magnetic attraction. It is this tendency to leave areas of relatively few opportunities which makes migration a basic avenue of adjustment or equalization of opportunities to the individuals in different locations.

It should be noted further that interest in this study is in migration only of those people who were in working ages (defined as 15-69) as of the end of the decade. The reason is simply that these are the people who are most affected and are involved in the economic activity of their parishes. They represent, in some sense, the supply of labor. Those in younger age groups simply "go along" with their parents. As for those aged 70 and over, there really is not much migration among this group, and what there is certainly is not motivated by the same forces as is the case for those in the working ages.

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[1] This is not to say that net outmigration is necessarily bad for the people remaining in the given area. In fact, outmigration from areas having a surplus of labor relative to demand works to the economic good of those remaining. This is generally the case in agricultural areas where large numbers of farm workers have been displaced by mechanization, crop acreage reductions, etc.

[2] If the differences are only imagined, the result is not quite the same. In this case the migrants do not find improved conditions in their new location. They tend to drift back to their old homes; or if they stay in their new location, they may be on relief, unemployed, or only partially employed. In either case, they do not represent expanded markets for business.

[3] See, for example, Carter Goodrich, Bushrod W. Allen, C. Warren Thorntwaite, and others, *Migration and Economic Opportunity* (Philadelphia: University of Pennsylvania Press, 1936), p. 504; C. E. Lively and Conrad Taeuber, *Rural Migration in the United States,* Works Progress Administration Research Monograph XIX (Washington: U. S. Government Printing Office, 1939), pp. 73, 74, 79, and 80; Donald J. Bogue, Henry S. Shryok, Jr., and Siegried A. Hoermann, *Subregional Migration in the United States, 1935-1940,* Vol. 1, Studies in Population Distribution No. 5 (Oxford, Ohio: Scripps Foundation, 1957), pp. 8, 9, and 75; Daniel O. Price, "Some Socio-Economic Factors in Internal Migration," *Social Forces,* Vol. 29 (May, 1951), pp. 409-415; Warren S. Thompson, *Population Problems* (New York: McGraw-Hill, 1953), p. 402; and Roger L. Burford, "An Index of Distance as Related to Internal Migration," *Southern Economic Journal,* Vol. XXIX (October, 1962), pp. 77-81.

Migration Defined

It should be made clear at the outset just what is meant here by the term "migration." In its most general sense, migration refers to any change in residence of an individual or family, ranging from a move across the street to one across the nation or across national boundaries. For the purpose of a study such as the present one, however, in which there is the need to measure migration in some empirically meaningful fashion, such a definition is of little use. Data pertaining to movements of population **within** small political jurisdictions are not available in generally useful form, and only changes of residence which result in the crossing of the boundaries of such jurisdictions as cities, counties, parishes, or larger units provide promising possibilities of documentation. Thus, migration as the term is used here refers to movements of place of residence which result in the crossing of one or more parish boundaries in Louisiana.

It is also necessary to distinguish between inmigration, outmigration, and net migration. The first two are self-explanatory—the total number of people moving their residence into a particular parish and the number moving out, respectively. Gross migration is simply the sum of inmigration and outmigration, ignoring algebraic signs. That is, it is the total number of people moving their residence across the boundaries of the parish of interest, whether in or out.

Finally, net migration is the algebraic difference between inmigration and outmigration. It is the surplus of those moving in over those moving out or vice versa. If there is positive net migration, the parish gained more people through migration than it lost. On the other hand, negative net migration indicates that the parish lost more people through migration than it gained.

Each of these might be convenient ways of looking at migration, depending on the purposes to be served. The earlier discussion of the economic significance of migration, however, implies net migration. Therefore, this is the view taken here. Thus, this is a study of net migration into or out of the individual parishes of Louisiana, into or out of the state, and into or out of the rural and urbanized areas of the state. The study relates particularly to the periods 1940 to 1950 and 1950 to 1960.

The Measurement of Migration

The measurement of migration between nations is a relatively simple matter. Fairly accurate records are kept as to the movements of individuals across national boundaries. This is not true, however, of internal migration (the movements of people within the nation). Hence, it has been necessary to devise statistical techniques by which such measurements can be made.

These techniques are based upon the distinction between population change, on the one hand, and migration on the other. Migration is only one component of population change. The population of a parish might increase or decrease as a result of net migration, or because of an excess or deficiency of births over deaths (natural increase or decrease). In fact, it is entirely possible for a parish to have a fairly large net outmigration and yet at the same time have an increase in its total population. Interest here is not in population change itself, but rather in its migration component.

There are several well-developed methods for measuring internal migration.[4] The method used in this study is the survival rates method, using national census-computed survival rates. A very brief outline of this method will be given here. First, let P_{bi} represent the number of people in a specific age-race-sex group (for example, male white aged 5-9) in a parish at the beginning of a decade according to the *U. S. Census of Population* and P_{ek} the number of people in that same race and sex group but ten years older (i.e., male white aged 15-19) at the end of the decade. Also, let $\overline{P}_{ek}$ represent the number of people in the parish who would have been in the latter group at the end of the decade if there had been no migration. Furthermore, let N_{bi} and N_{ek} be the national counterparts of P_{bi} and P_{ek}, respectively. The national age-race-sex specific survival rate (the proportion of the group who survived the decade) is

$$R_i = N_{ek}/N_{bi}.$$

If it is assumed that age-race-sex specific survival rates are at least approximately the same in a given parish as in the nation, then expected population within the group in that parish at the end of the decade is given by

$$\overline{P}_{ek} = R_i \bullet P_{bi}.$$

Net migration is, then, the difference between the number of people actually in the group at the end of the decade and the number expected to be there. That is to say,

$$M_k = P_{ek} - \overline{P}_{ek},$$

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[4] For a detailed discussion and evaluation of methods of measurement see: Roger L. Burford, *Net Migration for Southern Counties, 1940-1950 and 1950-1960,* Research Paper Number 24, Bureau of Business and Economic Research, Georgia State College, Atlanta, Georgia, (January, 1963), pp. 11-24. See also, A. J. Jaffe, *Handbook of Statistical Methods for Demographers,* (Washington: U. S. Government Printing Office, 1951), p. 179; Jacob S. Siegel and C. Horace Hamilton, "Some Considerations in the Use of the Residual Method of Estimating Net Migration," *Journal of the American Statistical Association,* Vol. 47 (September, 1952), pp. 475-500; Daniel O. Price, "Estimation of Two Sources of Error in the Estimation of Net Internal Migration," *Journal of the American Statistical Association,* Vol. 50 (September, 1955), pp. 689-700; and James D. Tarver, "Evaluation of Census Survival Rates in Estimating Intercensal State Net Migration," *Journal of the American Statistical Association,* (December, 1962), pp. 841-862.

where M_k is age-race-sex specific net migration in or out of the parish. If there was net outmigration M_k would be negative; if net inmigration, M_k would be positive. Moreover, the rate of net migration for the group is given by

$$R_k = (M_k/\overline{P}_{ek}) \cdot 100.$$

These are the working formulas used in the estimation of net migration for this study. The references cited in Footnote 4 give complete and detailed justification for these. It should be noted that the method of estimation outlined here applies only to those people who were alive at the beginning of the decade. That is to say, it does not apply to those born during the decade. For the purposes of the present study this presents no problem since interest here is only in those people who were in working ages at the end of the decade under study.

The Patterns of Migration

Figures I through IV depict the changes taking place in Louisiana's labor-force aged population through migration during the past two decades. Figures V and VI show the geographic shifts of the population between parishes as a result of migration. An analysis of these figures can provide some important insights into relative conditions which have existed in the respective parishes and can give some clues as to economic opportunities and problems that are likely to arise as a result of this migration.

Net Migration for the State as a Whole

Look first at Figures I and II. Here the rate of net migration in or out of the state is shown by age, race, and sex for 1940-50 and for 1950-60, respectively. One thing is obvious immediately upon looking at these charts: outmigration was generally much greater for the nonwhite than for the white population during both periods.

During the period 1940-50, there were high rates of outmigration for all ages of nonwhite population except those aged 65-69 in 1950. This was true for both males and females. The highest rates of outmigration were for those within the ages 20 to 39 in 1950. Somewhat surprising at first glance were the high rates of inmigration for both male and female nonwhites aged 65-69. After some reflections, it seems clear that this probably results primarily from a return to Louisiana for retirement of nonwhites who migrated out earlier. The public welfare programs in Louisiana are considerably more liberal than in most other states. This, plus the fact that Louisiana was "home" to these people, probably attracts them back for retirement. The high rate for this group might result partially also from misstatement of age by some to collect old age assistance. Approximately the same age-sex pattern of migration rates held for nonwhites in both of the decades studied.

For whites the picture is different. Generally for both decades, net migration rates were smaller for whites than for nonwhites. Moreover,

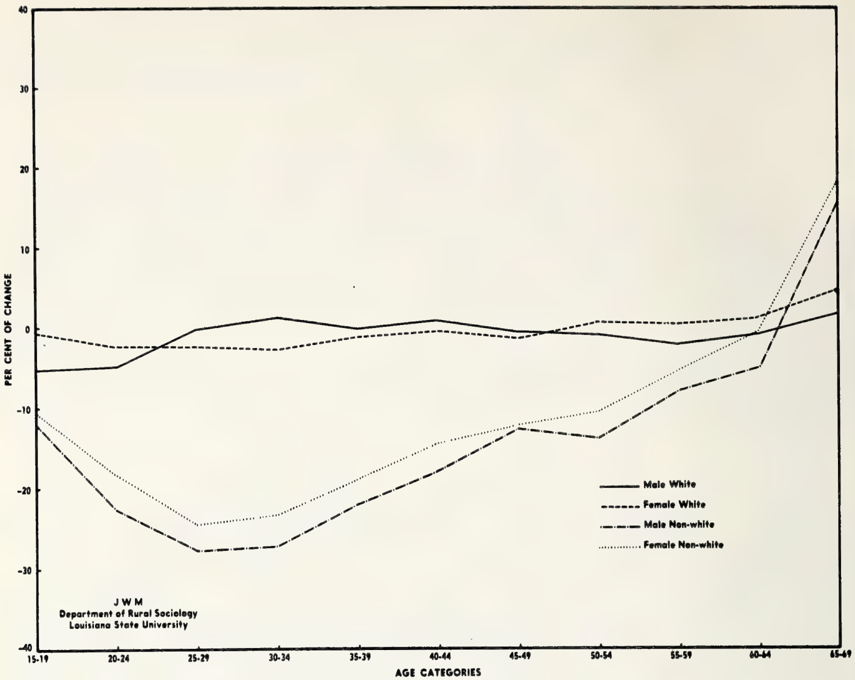


FIGURE I.—Rate of Net Migration for the Population Aged 15-69, by Race and Sex, Louisiana, 1940-50.

whereas migration was generally **out** for nonwhites during both decades, this is not true for whites. During 1940-50 net migration was **out** for whites, but during 1950-60 it was **in.** Moreover, although the net was **out** for both white males and females aged 15-24 in 1960, it was **in** for both sexes in all other age groups during 1950-60. The highest rates of net inmigration for white males during 1950-60 was for those aged 25 to 34 years. For white females the highest rate was for those aged 65-69 in 1960. A somewhat similar age-sex pattern held for whites during the 1940-50 period except that the net migration rates were generally lower or negative.

On the whole, the age-race-sex migration patterns depicted in Figures I and II probably work to the economic betterment of the state. There have been net movements into the state of white males in their "prime" productive ages. There has been heavy net outmigration of nonwhites of all ages and both sexes (except the very old). These, in the past, have generally had less education and skill than their white counterparts. As a result of this and other factors, they have had lower earning capacities and have, as a result, contributed less to the economic life of the state than their white counterparts. Moreover, modern industry tends to have a strong interest in the level of education of the people of areas into which it might move or expand. On the other hand, the high rates of net **in**migration of people aged 65-69 offers at least potential welfare

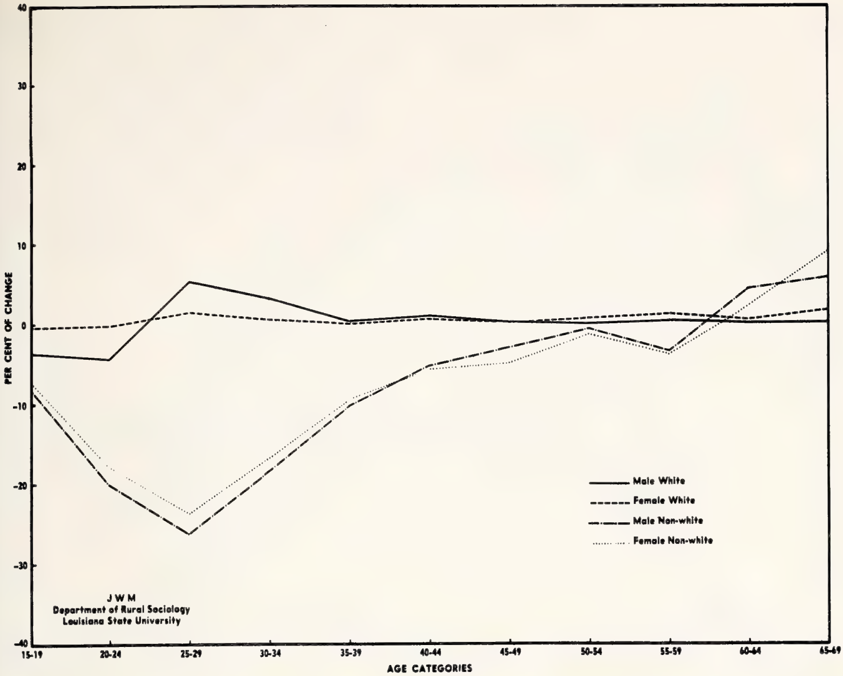


FIGURE II.—Rate of Net Migration for the Population Aged 15-69, by Race and Sex, Louisiana, 1950-60.

problems. That is to say, although net inmigration to an area generally contributes to the economic betterment of that area, this is not always necessarily so. Nor is net outmigration always detrimental to an area. Whether in- or outmigration is for the good or bad of an area depends, among other things, on the "quality" (in terms of skill and education) of the migrants relative to the rest of the population in the area and the economic opportunities for those people existing in the area.

Rural-Urban Migration

Look now at Figures III and IV. The most obvious thing depicted here is that in the period 1950 to 1960 there were high rates of net **in**migration for all age-race-sex groups in Louisiana's urbanized areas and high rates of net **out**migration for all such groups in rural areas.

The highest rates of net **in**migration into urbanized areas were for male and female whites aged 20-29. Females reached their peak at 20-24, whereas the peak for male whites was at ages 25-29.

The highest rates of **out**migration from rural areas for male and female whites was in age group 20-24 in 1960. For both male and female nonwhites the peak rate of **out**migration was in ages 25-29.

It is clear from these two charts that, while Louisiana's rural population is becoming older as a result of high rates of outmigration of

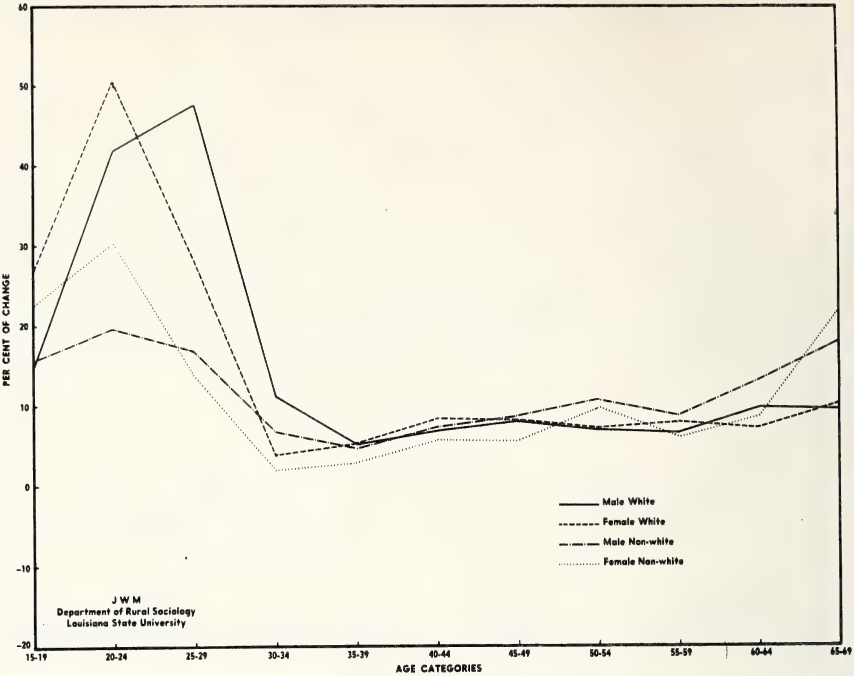


FIGURE III.—Rate of Net Migration for Urban Areas of Louisiana for the Population Aged 15-69, by Race and Sex, 1950-60.

young people, the urban population is becoming younger for the same reason. Generally too, and even more obvious, there has been a definite shift of population from rural to urban areas. It should be noted, however, that the population movements depicted in Figures III and IV are not just movements from farm to city within Louisiana. Many of the people leaving the rural areas did not move to a city within the state, but rather to a city or rural area in some other state. Similarly, not all of those moving into urbanized areas within the state moved from the state's rural areas. Many migrated from cities or rural areas of other states.

This movement, basically from farm to city (though from state to state as well), reflects mainly differences in economic opportunities either real or imagined in other areas. People move mainly from areas with few or declining employment opportunities to areas of a greater abundance of such opportunities.

Net Migration in Louisiana's Parishes

Shown in Figures V and VI are the percentage rates of net migration in or out of the individual parishes for the total population within the age-race-sex groups shown in Figures I through IV. Figure V depicts net migration for parishes during 1940-50 and Figure VI shows the same data for 1950-60. The appendix contains data on net migration for

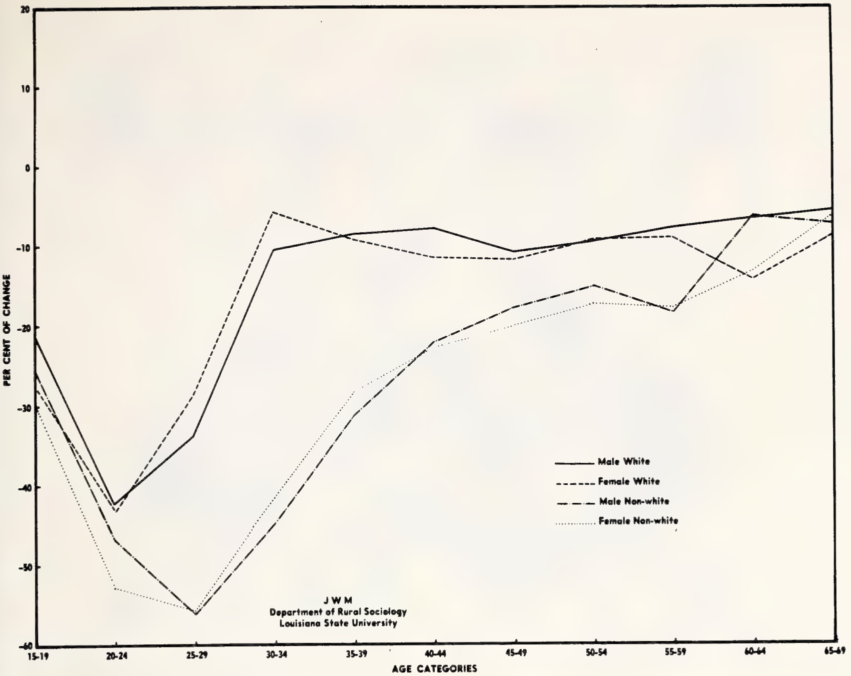


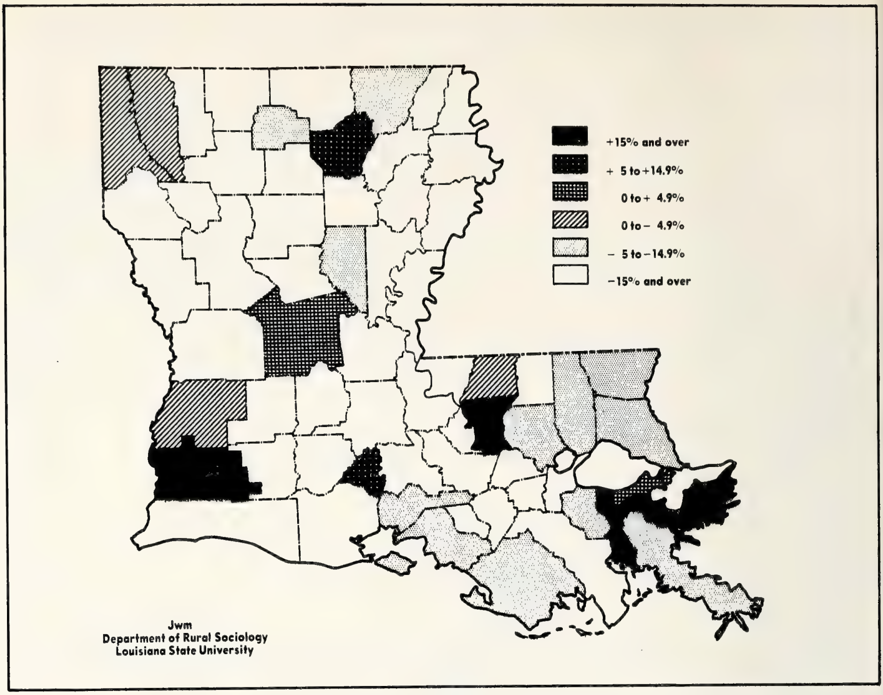
FIGURE IV.—Rate of Net Migration for Rural Areas of Louisiana for the Population Aged 15-69, by Race and Sex, 1950-60.

each age-race-sex group for each of Louisiana's parishes for the two periods, 1940-50 and 1950-60.

During the 1940-50 decade, only eight parishes (Ouachita, Rapides, Calcasieu, Lafayette, East Baton Rouge, Jefferson, Orleans, and St. Bernard) had net inmigration. All other parishes had net outmigration rates ranging from a low of 0.5 per cent in Bossier to a high of 41.2 per cent in Red River Parish. The highest rate of net inmigration was 65.5 per cent in Jefferson Parish followed by 50.6 per cent in East Baton Rouge Parish. Generally, as would be expected, net migration tended to be negative in rural parishes and positive in urban and suburban parishes.

During the 1950-60 decade, the general pattern of migratory flow was roughly the same as during 1940-50. During this decade, however, more parishes (15) had net inmigration. Moreover, two parishes (Orleans and Rapides) which had net inmigration during 1940-50, had net outmigration in 1950-60. Parishes which had net outmigration during 1940-50 but net inmigration during 1950-60 were Caddo, Concordia, Lafourche, Livingston, Plaquemines, St. Mary, St. Tammany, Terrebonne, and West Feliciana.

It should be noted that the rather high rates of net inmigration in Jefferson, Plaquemines, St. Bernard, and St. Tammany parishes, accompanied by the net outmigration from Orleans Parish, largely reflects movements to the suburbs. This is a movement which was common to



Jwm
Department of Rural Sociology
Louisiana State University

FIGURE V.—Rate of Net Migration of Population Aged 15-69, by Parish, Louisiana, 1940-50.

most large metropolitan centers throughout the nation during the 1950s. Again, as during the 1940s, most of the parishes gaining population through migration were urban or suburban parishes. Those losing population through migration were, for the most part, rural parishes. This is a reflection primarily of declining employment opportunities in farming on the one hand and increasing opportunities in urban areas on the other. Through the process of migration **from** areas of few **to** areas of many opportunities, income potentials of people in all areas tend to be more nearly equalized.

Prospects for Future Migration

It is likely that the trends of the past two decades will continue largely unchanged during the 1960-70 period. More parishes will have net inmigration during the 1960s than during the 1950s. Those parishes most likely to gain by migration during the 1960s are urban parishes, those parishes adjoining urban centers, several nonurban parishes on the Mississippi River, and perhaps a few other nonurban parishes probably in the coastal area. There are many reasons for this outlook. Most of the reasons are economic in nature. People tend to migrate into areas of greatest economic opportunity. These are generally urban or other industrialized areas. Industry in turn tends to locate either near its source of raw materials, labor supply, etc., near its market concentrations

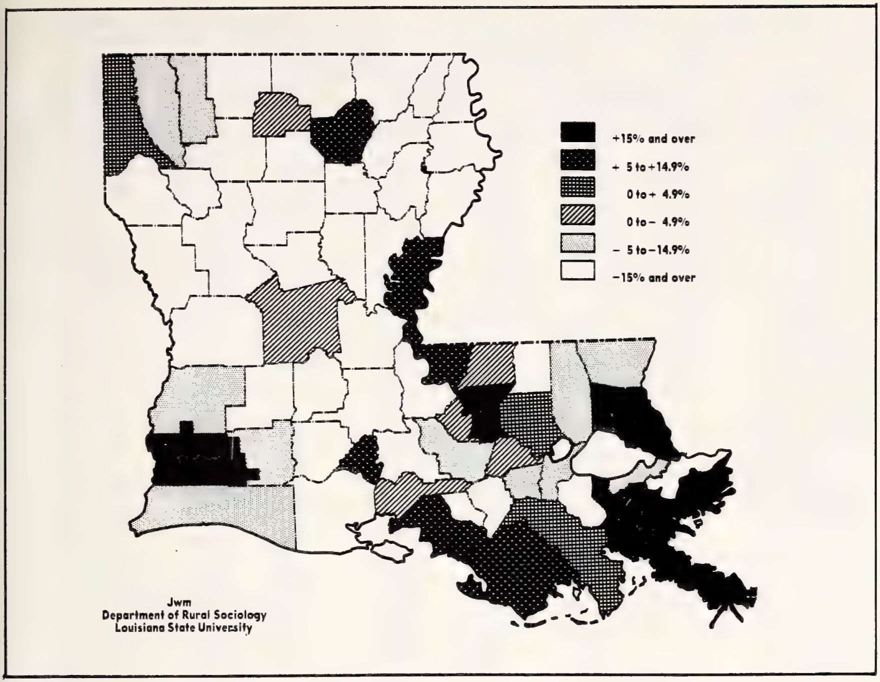


FIGURE VI.—Rate of Net Migration of Population Aged 15-69, by Parish, Louisiana, 1950-60.

(usually urban centers), or near cheap dependable transportation. This outlook is based partly upon the earlier analysis of this report and partly upon other work done by the author.[5]

All of this is grossly oversimplified, but it is sufficient to point up general areas of greatest growth in the future. In general, the economic outlook for Louisiana is optimistic, especially for south Louisiana. According to Donald J. Bogue, the whole southern coastal region from coastal South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas to the Mexican border is likely to be one of the fastest growing regions in the nation.[6] Hence, Louisiana, along with at least the southern parts of its neighboring states, may be expected to continue to grow and prosper for the foreseeable future.

Along with such shifts in population, however, come many problems—problems of congestion, schools, etc., in the growing areas, and a host of problems of other kinds related to declining communities. These problems must be faced and the means for their solution must be found.

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[5] Roger L. Burford, "A Projections Model for Small Area Economies" (pending publication); and "Econometric Forecasts of Migration, Population, Employment, and Other Economic Variables for Louisiana Parishes" (pending publication by the Louisiana Department of Public Works).

[6] Donald J. Bogue, "Population Growth in the United States," *Population Bulletin*, Vol. XX, No. I (February, 1964), p. 23.

APPENDIX I.—Net Migration by Age, Race, and Sex for Louisiana Parishes, 1940-1950

Parish and Age	Race and Sex							
	White				Nonwhite			
	Male		Female		Male		Female	
	No.	%	No.	%	No.	%	No.	%
Acadia								
15-19	–451	–20.7	–420	–19.4	–85	–16.3	–74	–13.8
20-24	–674	–30.8	–814	–35.2	–167	–35.3	–136	–25.6
25-29	–622	–32.2	–622	-30.4	–133	–32.3	–167	–36.3
30-34	–356	–21.4	–499	–27.3	–111	–33.6	–97	–26.6
35-39	–320	–19.4	–294	–18.1	–53	–17.1	–82	–21.5
40-44	–204	–14.7	–167	–12.2	15	7.2	–19	8.1
45-49	–129	–10.7	–176	–14.3	–48	–21.6	1	0.3
50-54	–117	–12.7	–122	–12.1	19	12.0	–1	–0.6
55-59	–59	–8.2	–84	–11.6	–9	–6.8	2	1.5
60-64	–35	–6.6	–17	–2.9	–7	–6.8	18	19.9
65-69	–21	–4.2	–23	–4.7	23	25.6	32	30.2
Allen								
15-19	–74	–11.5	–105	–14.7	–23	–10.7	–18	–8.3
20-24	–206	–29.6	–180	–24.9	–96	–45.1	–90	–36.4
25-29	–192	–28.1	–198	–28.6	–90	–40.2	–65	–29.8
30-34	–75	–12.7	–104	–17.4	–62	–35.7	–66	–32.5
35-39	–79	–14.1	–50	–9.7	–18	–10.4	–34	–17.0
40-44	29	6.4	–22	–4.8	–37	–23.8	–53	–29.4
45-49	–33	–7.8	–21	–5.0	–16	–11.5	–12	–8.4
50-54	0	–0.1	–16	–5.2	–45	–32.4	–38	–28.9
55-59	–1	–0.5	8	2.6	–16	–15.0	–16	–18.5
60-64	-7	–2.9	–21	–8.1	–15	–18.0	8	11.8
65-69	1	0.5	–1	–0.6	–16	–18.9	15	21.6
Ascension								
15-19	–101	–14.8	–98	–13.9	–45	–11.9	–46	–12.2
20-24	–265	–34.1	–253	–33.7	–120	–32.4	–132	–32.6
25-29	–219	–29.1	–204	–27.3	–198	–49.8	–193	–43.3
30-34	–107	–16.5	–71	–12.4	–145	–44.4	–56	–19.0
35-39	–58	–11.0	–43	–9.4	–92	–32.1	–87	–28.9
40-44	–10	–2.3	–18	–4.2	–42	–18.5	–30	–13.1
45-49	–10	–2.5	–42	–10.3	–16	–7.5	7	3.5
50-54	–22	–6.4	–3	–0.8	–12	–8.2	–24	–13.2
55-59	–38	–12.7	1	0.3	–6	–4.1	0	0.0
60-64	27	11.2	–5	–2.0	9	6.7	9	7.4
65-69	4	2.0	21	10.1	27	18.3	22	11.8
Assumption								
15-19	–147	–25.4	–193	–30.9	–71	–17.9	–69	–19.4
20-24	–252	–44.0	–298	–47.2	–140	–38.2	–147	–37.8
25-29	–260	–42.8	–303	–48.2	–207	–51.9	–188	–41.9
30-34	–176	–34.9	–163	–33.5	–179	–50.7	–136	–44.8
35-39	–86	–18.3	–80	–18.8	–109	–37.8	–57	–22.9
40-44	–96	–24.4	–61	–18.1	–26	–13.4	–9	–5.2
45-49	–27	–9.0	–27	–9.2	–56	–29.9	–40	–20.2
50-54	–47	–17.8	–30	–10.6	–19	–12.4	–19	–12.5
55-59	–29	–13.3	–42	–18.4	15	9.9	6	4.7
60-64	–12	–6.0	–16	–7.2	–24	–20.2	–15	–14.6
65-69	–14	–9.3	–17	–9.2	16	14.8	17	11.3
Avoyelles								
15-19	–347	–22.8	–395	–25.5	–86	–13.7	–143	–22.4
20-24	–682	–43.2	–710	–43.2	–213	–38.5	–256	–39.5
25-29	–515	–34.8	–604	–38.1	–221	–42.8	–296	–52.3
30-34	–314	–24.0	–301	–22.5	–201	–48.4	–222	–47.1
35-39	–272	–20.8	–218	–18.9	–122	–34.3	–100	–25.4
40-44	–147	–14.0	–115	–11.6	–89	–27.2	–58	–18.0
45-49	–140	–14.9	–87	–10.4	–58	–21.7	–29	–11.6
50-54	–108	–13.5	–104	–14.0	–44	–20.0	–48	–21.4
55-59	–42	–6.7	–40	–6.3	–7	–4.4	–19	–11.3
60-64	13	2.7	6	1.2	–15	–12.8	20	17.1
65-69	18	4.8	20	4.7	26	19.0	16	9.8

APPENDIX I.—(Continued)

Parish and Age	Race and Sex							
	White				Nonwhite			
	Male		Female		Male		Female	
	No.	%	No.	%	No.	%	No.	%
Beauregard								
15-19	–42	–6.2	–56	–8.7	NA	–13.0	5	4.0
20-24	–220	–36.3	–160	–24.6	NA	–16.5	–20	–13.9
25-29	–179	–29.1	–168	–25.7	NA	–16.6	–10	–8.2
30-34	–17	–3.5	–6	–1.2	NA	–23.6	8	9.6
35-39	32	6.5	33	6.3	NA	4.6	–10	–9.2
40-44	78	17.3	57	14.5	NA	13.7	13	14.3
45-49	63	17.1	17	4.8	8	11.7	–1	–1.5
50-54	60	21.5	17	5.6	8	12.4	–8	–8.7
55-59	26	10.6	14	4.6	–1	–1.6	–2	–3.8
60-64	32	13.0	19	7.1	4	6.3	–5	–10.3
65-69	37	17.9	37	18.1	25	44.0	17	34.3
Bienville								
15-19	–234	–34.7	–244	–39.9	–209	–30.2	–210	–28.9
20-24	–363	–60.8	–421	–65.3	–277	–45.2	–358	–52.0
25-29	–446	–66.4	–380	–61.5	–367	–62.5	–267	–58.8
30-34	–265	–49.5	–195	–37.1	–255	–51.2	–253	–47.2
35-39	–140	–29.8	–109	–22.5	–201	–46.6	–185	–39.5
40-44	–88	–18.5	–79	–18.9	–147	–38.4	–111	–28.7
45-49	–83	–21.7	–90	–21.7	–92	–30.0	–87	–29.0
50-54	–30	–9.0	–60	–17.7	–65	–26.2	–36	–16.1
55-59	–36	–12.4	–29	–10.1	–17	–10.6	–10	–6.8
60-64	–18	–6.6	2	0.6	–31	–21.9	–12	–10.5
65-69	–9	–4.3	–26	–11.0	33	24.5	20	14.9
Bossier								
15-19	534	84.8	86	13.0	–261	–29.1	–261	–28.8
20-24	1530	248.5	466	66.9	–266	–34.1	–399	–44.6
25-29	805	78.8	911	125.2	–414	–54.2	–427	–51.4
30-34	–286	–15.4	446	58.1	–335	–52.8	–377	–49.6
35-39	–149	–13.1	104	13.4	–308	–49.1	–264	–38.8
40-44	–57	–6.6	–68	–10.2	–217	–37.2	–185	–31.7
45-49	–67	–10.6	27	5.7	–157	–30.2	–129	–26.3
50-54	–44	–9.5	–27	–7.0	–114	–28.1	–119	–28.5
55-59	–47	–13.8	16	5.9	–56	–17.7	–33	–12.1
60-64	15	6.4	41	17.3	–65	–27.5	–63	–26.3
65-69	–14	–7.2	14	8.6	24	9.8	55	23.6
Caddo								
15-19	–85	–2.7	410	12.6	–162	–6.3	–96	–3.5
20-24	630	18.2	1773	49.3	–486	–18.6	–34	–1.1
25-29	1376	37.5	1286	30.8	–651	–24.5	–649	–19.4
30-34	892	23.7	89	1.9	–659	–27.0	–804	–24.2
35-39	101	2.4	–38	–0.8	–760	–27.9	–874	–25.5
40-44	–96	–2.4	–181	–4.1	–591	–24.6	–751	–25.3
45-49	–107	–3.0	–118	–3.1	–459	–20.0	–640	–23.3
50-54	–95	–3.0	96	3.3	–408	–22.0	–338	–16.9
55-59	–76	–3.1	130	5.7	–182	–13.5	–92	–7.2
60-64	–32	–1.8	181	10.7	–92	–10.6	25	2.9
65-69	75	5.9	179	12.9	405	53.4	458	46.5
Calcasieu								
15-19	518	26.6	756	39.6	–12	–1.7	148	19.3
20-24	561	27.2	1017	49.4	118	17.6	202	24.2
25-29	1163	61.9	1199	59.2	127	18.5	157	29.3
30-34	1014	55.6	846	41.5	128	21.0	–23	–3.2
35-39	879	44.4	630	31.4	67	11.0	46	6.3
40-44	641	34.3	558	31.4	38	7.3	–5	–1.0
45-49	495	32.8	345	23.9	90	19.3	71	16.5
50-54	284	23.1	185	15.9	33	8.7	–4	–0.9
55-59	187	19.9	141	14.9	54	17.3	13	4.6
60-64	82	10.7	139	19.6	45	19.9	22	10.2
65-69	107	18.6	58	9.3	48	19.5	41	16.8

APPENDIX I.—(Continued)

Parish and Age	Race and Sex							
	White				Nonwhite			
	Male		Female		Male		Female	
	No.	%	No.	%	No.	%	No.	%
Caldwell								
15-19	–109	–25.5	–191	–41.4	–39	–20.5	–58	–28.6
20-24	–291	–58.3	–244	–51.1	–91	–47.8	–110	–50.7
25-29	–214	–48.6	–252	–51.5	–119	–66.5	–116	–60.4
30-34	–147	–38.1	–156	–41.1	–86	–59.7	–80	–49.8
35-39	–106	–30.9	–91	–26.6	–18	–18.5	–29	–25.6
40-44	–56	–18.9	–60	–21.9	–28	–26.8	–29	–28.6
45-49	–71	–26.4	–41	–16.3	–9	–11.6	–20	–21.8
50-54	–10	–4.7	–39	–17.6	–3	–4.4	–1	–1.3
55-59	–31	–14.7	–24	–12.2	–3	–5.3	–12	–24.4
60-64	–6	–3.3	–5	–3.6	–3	–5.3	–12	–24.4
65-69	–3	–2.6	–12	–9.3	–12	–24.5	–5	–12.4
Cameron								
15-19	–102	–30.2	–139	–37.3	–8	–18.2	–14	–41.0
20-24	–154	–38.7	–158	–42.3	–8	–18.6	–16	–43.0
25-29	–111	–35.0	–118	–37.5	–19	–52.3	–25	–61.3
30-34	–100	–34.6	–127	–41.7	–19	–44.6	–1	–4.4
35-39	–112	–33.4	–96	–31.9	–2	–10.3	–8	–27.7
40-44	–95	–33.0	–70	–26.5	–6	–23.6	–6	–36.3
45-49	–48	–20.5	–56	–27.4	–1	–8.1	–2	–17.9
50-54	–34	–17.3	–31	–18.1	–2	–11.4	–1	–12.1
55-59	–35	–24.5	–30	–24.3	–4	–38.8	1	7.3
60-64	–34	–34.0	–16	–22.4	–4	–44.7	–4	–58.4
65-69	–21	–25.9	–9	–12.4	–1	–8.2	2	45.4
Catahoula								
15-19	–219	–36.9	–216	–37.7	–105	–36.3	–128	–41.0
20-24	–318	–55.9	–357	–62.5	–181	–60.9	–189	–56.5
25-29	–245	–52.2	–232	–50.1	–137	–60.0	–109	–45.8
30-34	–160	–41.8	–153	–38.2	–99	–51.9	–109	–46.9
35-39	–79	–21.5	–99	–28.7	–75	–39.0	–101	–42.6
40-44	–92	–26.1	–118	–34.2	–84	–41.5	–38	–22.0
45-49	–65	–21.9	–53	–21.1	–45	–31.5	–41	–26.1
50-54	–71	–27.4	–65	–30.6	–44	–32.7	–37	–30.0
55-59	–23	–13.0	–26	–15.3	–20	–23.8	–10	–12.5
60-64	–49	–27.6	–24	–18.3	–32	–41.0	–8	–11.1
65-69	3	2.8	–18	–16.5	5	5.8	21	25.2
Claiborne								
15-19	–124	–20.4	–134	–22.6	–300	–29.5	–403	–37.8
20-24	–339	–49.0	–301	–45.6	–538	–55.4	–553	–52.0
25-29	–273	–39.1	–278	–39.8	–626	–65.6	–640	–59.7
30-34	–103	–20.9	–92	–16.2	–480	–62.4	–417	–53.3
35-39	2	0.6	–43	–9.3	–261	–42.7	–350	–49.3
40-44	–9	–2.2	–43	–8.8	–180	–37.7	–163	–30.9
45-49	–14	–3.4	–86	–17.9	–160	–33.9	–114	–25.8
50-54	–27	–6.8	–53	–13.9	–95	–27.6	–82	–23.5
55-59	–21	–6.2	–34	–9.4	–65	–26.2	–46	–19.4
60-64	3	1.0	–35	–12.3	–11	–5.7	–33	–17.8
65-69	–15	–6.3	4	2.0	21	10.7	18	8.9
Concordia								
15-19	13	5.5	–1	–0.5	–75	–18.0	–60	–13.1
20-24	–18	–7.5	–58	–21.6	–206	–50.1	–148	–32.1
25-29	–30	–12.3	21	9.1	–193	–49.6	–253	–52.5
30-34	10	5.3	7	3.3	–174	–47.6	–178	–40.6
35-39	–6	–2.8	–22	–10.6	–156	–43.3	–122	–27.8
40-44	3	1.5	–5	–2.8	–118	–34.5	–133	–33.8
45-49	2	1.0	13	8.8	–117	–33.6	–102	–30.1
50-54	–5	–3.1	17	14.3	–85	–32.3	–28	–10.7
55-59	–9	–7.0	–4	–3.8	–42	–18.7	–19	–9.8
60-64	0	0.0	7	11.1	–18	–11.2	18	13.5
65-69	1	1.6	–7	–11.0	10	6.0	–14	–6.7

APPENDIX I.—(Continued)

Parish and Age	Race and Sex							
	White				Nonwhite			
	Male		Female		Male		Female	
	No.	%	No.	%	No.	%	No.	%
DeSoto								
15-19	–134	–24.7	–143	–27.1	–480	–42.1	–517	–43.8
20-24	–308	–53.2	–256	–43.1	–704	–67.1	–762	–61.7
25-29	–278	–49.2	–296	–48.2	–711	–67.5	–655	–64.3
30-34	–178	–35.2	–106	-21.9	–609	–68.4	–506	–56.1
35-39	–93	–21.0	–81	–18.0	–373	–54.7	–348	–47.7
40-44	–32	–8.2	–36	–9.1	–233	–41.7	–208	–34.2
45-49	–53	–14.6	–32	–8.8	–154	–31.3	–225	–39.0
50-54	–49	–15.3	–50	–15.4	–154	–36.6	–94	–22.8
55-59	–13	–4.4	4	1.2	–57	–16.6	–88	–26.0
60-64	–17	–6.3	–15	–6.1	–76	–29.1	–68	–25.3
65-69	–5	–1.9	–1	–0.5	31	12.2	–6	–2.0
East Baton Rouge								
15-19	1542	71.2	1726	78.2	732	57.7	932	69.5
20-24	3432	146.1	3208	121.9	823	62.0	1111	68.8
25-29	3212	128.9	2876	101.4	635	43.5	586	30.9
30-34	2221	86.8	1627	52.7	435	33.4	317	18.2
35-39	1489	53.9	1161	39.0	364	24.6	227	12.1
40-44	922	35.1	863	32.9	243	18.3	273	17.9
45-49	609	27.6	541	24.4	175	15.7	112	8.6
50-54	494	25.5	469	27.0	125	14.6	89	9.0
55-59	228	16.4	331	24.3	100	14.3	125	18.5
60-64	225	22.3	291	30.5	106	21.3	146	29.2
65-69	135	20.9	306	42.3	291	64.7	289	47.6
East Carroll								
15-19	–84	–22.0	–71	–19.4	–149	–27.0	–181	–31.1
20-24	–157	–43.9	–130	–35.8	–266	–48.8	–242	–41.2
25-29	–95	–28.7	–125	–39.5	–317	–59.8	–332	–53.1
30-34	–81	–30.0	–82	–28.5	–307	–61.0	–307	–51.8
35-39	–42	–16.3	–44	–16.8	–277	–53.4	–227	–41.7
40-44	–44	–17.2	–60	–25.3	–168	–49.0	–243	–44.6
45-49	–56	–17.2	–34	–20.1	–179	–43.8	–178	–38.2
50-54	–23	–15.6	–21	–16.1	–147	–41.4	–100	–27.1
55-59	–21	–15.7	–29	–23.7	–62	–21.5	–23	–10.4
60-64	–25	–22.2	–21	–21.7	–42	–19.1	–40	–20.5
65-69	–8	–9.7	0	0.0	–11	–5.0	26	12.7
East Feliciana								
15-19	79	62.2	26	17.9	–121	–19.6	–191	–28.9
20-24	93	57.4	36	20.7	–155	–26.4	–282	–43.5
25-29	66	35.5	71	37.6	–227	–39.7	–253	–45.1
30-34	71	32.2	73	39.6	–93	–22.9	–122	–28.1
35-39	70	27.0	104	48.2	–99	–22.6	–62	–14.9
40-44	76	25.6	114	49.0	–10	–2.7	–7	–2.1
45-49	54	17.7	102	40.0	–10	–3.2	–10	–2.8
50-54	22	8.7	99	37.7	–13	–5.1	–15	–5.5
55-59	28	14.2	57	24.6	–7	–3.4	–11	–4.5
60-64	49	24.6	22	9.9	2	1.0	–21	–10.2
65-69	6	3.3	32	16.2	37	20.1	–9	–3.8
Evangeline								
15-19	–281	–21.8	–252	–20.0	–109	–19.7	–114	–22.7
20-24	–477	–34.4	–394	–30.8	–114	–27.7	–154	–33.1
25-29	–310	–26.0	–305	–26.8	–120	–37.1	–147	–36.0
30-34	–243	–20.8	–234	–20.3	–85	–30.6	–128	–39.1
35-39	–196	–17.6	–157	–14.9	–67	–24.6	–57	–20.7
40-44	–133	–13.5	–112	–12.7	–17	–10.3	–38	–23.9
45-49	–126	–14.8	–53	–6.7	–26	–16.2	–20	–12.6
50-54	–41	–6.3	–41	–6.7	–19	–15.4	–18	–16.2
55-59	–42	–8.0	–11	–2.3	–15	–14.7	–5	–6.5
60-64	–7	–2.1	–3	–0.7	7	12.4	–4	–9.9
65-69	–2	–0.7	–14	–5.0	8	13.3	8	13.6

APPENDIX I.—(Continued)

Parish and Age	Race and Sex							
	White				Nonwhite			
	Male		Female		Male		Female	
	No.	%	No.	%	No.	%	No.	%
Franklin								
15-19	–272	–23.7	–312	–26.1	–183	–25.5	–178	–24.9
20-24	–555	–47.3	–538	–50.1	–349	–51.8	–261	–38.7
25-29	–520	–49.3	–495	–45.0	–287	–53.6	–339	–49.5
30-34	–313	–33.9	–243	–26.9	–256	–51.2	–247	–45.9
35-39	–158	–19.6	–162	–20.4	–216	–43.6	–200	–35.8
40-44	–112	–14.7	–135	–19.3	–192	–44.3	–174	–37.9
45-49	–68	–11.9	–89	–15.3	–125	–31.2	–129	–32.4
50-54	–54	–11.7	–102	–23.7	–99	–32.2	–87	–30.4
55-59	–73	–19.7	–57	–15.4	–50	–22.2	–48	–22.9
60-64	–20	–6.5	5	1.9	–53	–33.9	–53	–36.6
65-69	–29	–11.6	–43	–16.4	23	13.1	12	6.5
Grant								
15-19	–219	–32.6	–206	–33.9	–42	–20.5	–38	–20.5
20-24	–370	–56.3	–338	–52.5	–96	–45.9	–77	–34.2
25-29	–365	–55.6	–297	–47.1	–126	–60.0	–114	–51.2
30-34	–155	–30.7	–120	–25.1	–105	–56.9	–68	–41.8
35-39	–105	–21.8	–80	–18.9	–66	–48.7	–66	–36.8
40-44	–80	–19.2	–67	–15.8	–23	–20.0	–17	–13.3
45-49	–41	–11.1	–53	–14.6	–53	–44.9	–39	–32.0
50-54	–50	–16.7	–43	–12.6	–29	–29.6	–9	–9.8
55-59	–15	–5.1	12	4.8	–8	–10.7	–10	–14.6
60-64	13	5.3	–20	–9.5	–5	–9.9	–13	–24.9
65-69	29	16.4	12	6.4	–4	–5.7	13	19.2
Iberia								
15-19	–153	–13.2	–117	–10.1	–94	–13.2	–125	–16.4
20-24	–246	–20.5	–87	–7.2	–184	–29.4	–229	–31.4
25-29	33	3.1	–97	–7.8	–253	–38.8	–286	–37.7
30-34	–99	–8.6	–135	–11.1	–268	–40.1	–235	–33.8
35-39	–75	–6.5	–110	–9.7	–178	–30.9	–134	–22.9
40-44	–98	–9.6	–112	–11.7	–107	–24.1	–76	–18.5
45-49	–86	–10.4	–8	–1.1	–27	–7.8	–59	–16.6
50-54	–44	–.9	–25	–4.2	–57	–21.2	–14	–5.1
55-59	–22	–4.4	37	7.1	–5	–2.4	–33	–14.6
60-64	–22	–5.3	–16	–3.8	1	0.5	–22	–12.4
65-69	8	2.6	5	1.3	–13	–6.4	6	2.9
Iberville								
15-19	–147	–22.4	–82	–13.1	–80	–13.0	–154	–23.7
20-24	–217	–29.1	–207	–28.5	–205	–35.7	–257	–40.1
25-29	–176	–25.0	–258	–32.9	–288	–44.7	–295	–43.9
30-34	–168	–25.7	–122	–19.8	–314	–48.6	–128	–24.7
35-39	–88	–15.6	–67	–12.2	–291	–44.2	–182	–31.9
40-44	–64	–12.8	–65	–14.1	–178	–35.5	–95	–20.5
45-49	–29	–6.6	–45	–10.6	–96	–22.0	–37	–9.4
50-54	–31	–8.5	–27	–7.5	–97	–26.9	–69	–18.7
55-59	–2	–0.5	2	0.6	–8	–2.8	0	0.0
60-64	–33	–12.3	–15	–5.7	–8	–3.6	–21	–8.4
65-69	7	3.5	–9	–4.6	26	10.2	109	38.0
Jackson								
15-19	–196	–30.7	–156	–24.7	–98	–34.8	–135	–36.7
20-24	–329	–49.3	–300	–46.3	–94	–40.6	–156	–45.3
25-29	–258	–45.6	–265	–41.8	–151	–54.8	–102	–35.7
30-34	–175	–31.2	–178	–29.5	–108	–46.9	–117	–45.6
35-39	–176	–30.1	–166	–27.2	–118	–46.9	–117	–45.6
40-44	–137	–25.9	–115	–24.2	–121	–49.9	–79	–35.8
45-49	–52	–13.6	–80	–23.3	–41	–24.7	–55	–33.4
50-54	–41	–14.9	–29	–10.0	–38	–28.9	–30	–26.6
55-59	–21	–8.9	–25	–8.7	–29	–29.3	–22	–30.3
60-64	–5	–2.3	–31	–14.6	–20	–30.4	–14	–21.9
65-69	–15	–8.0	–10	–5.9	–3	–5.3	8	11.2

APPENDIX I.—(Continued)

Parish and Age	Race and Sex							
	White				Nonwhite			
	Male		Female		Male		Female	
	No.	%	No.	%	No.	%	No.	%
Jefferson								
15-19	611	30.6	939	47.8	183	46.8	223	56.6
20-24	983	42.9	1713	81.2	241	61.7	330	72.0
25-29	2052	92.6	2348	106.1	232	60.3	283	63.0
30-34	1949	108.2	1977	105.1	202	61.8	271	74.9
35-39	1784	97.3	1604	82.5	201	61.0	237	67.3
40-44	1397	77.7	1267	71.6	196	60.8	181	50.2
45-49	880	55.6	661	40.3	200	68.6	178	61.0
50-54	681	49.1	486	36.6	85	30.5	83	31.2
55-59	354	34.4	478	49.8	116	67.4	66	43.9
60-64	267	35.9	332	46.2	18	12.9	28	20.6
65-69	185	32.4	210	35.0	58	40.2	72	43.9
Jefferson Davis								
15-19	–152	–15.4	–48	–5.2	–69	–19.6	–90	–22.1
20-24	–199	–20.8	–116	–12.1	–137	–39.0	–162	–40.5
25-29	–133	–15.1	–180	–19.3	–159	–53.4	–131	–42.4
30-34	–48	–6.3	–116	–13.8	–95	–42.6	–87	–31.6
35-39	–116	–13.8	–95	–12.1	–74	–32.0	–54	–24.6
40-44	–108	–13.7	–73	–10.1	–37	–22.7	–37	–20.4
45-49	–41	–7.2	–39	–6.7	68	–39.1	–46	–30.9
50-54	–21	–4.3	–283	–37.7	–13	–14.0	–14	–12.1
55-59	–22	–5.3	–17	–4.4	–11	–12.9	5	5.3
60-64	9	2.9	9	2.9	–14	–17.2	1	2.1
65-69	5	1.9	7	2.5	32	33.5	13	14.1
Lafayette								
15-19	312	21.2	516	37.2	–38	–4.6	–28	–3.2
20-24	728	47.9	557	34.8	–147	–18.9	–162	–17.2
25-29	475	32.2	210	12.6	–171	–23.6	–205	–25.0
30-34	293	21.2	93	6.0	–206	–32.2	–179	–25.6
35-39	219	16.4	105	7.3	–170	–26.5	–92	–15.6
40-44	156	13.6	88	7.2	–41	–10.0	–11	–2.6
45-49	134	12.9	127	12.5	12	3.4	–32	–8.4
50-54	12	1.5	63	7.5	–53	–19.1	25	9.2
55-59	46	6.7	78	11.4	–6	–2.8	34	16.5
60-64	–26	–4.6	8	1.4	2	0.9	14	9.2
65-69	13	3.2	32	6.9	10	6.5	–27	–13.8
Lafourche								
15-19	–220	–12.0	–186	–9.9	–35	–11.2	–82	–24.5
20-24	–378	–19.9	–412	–21.7	–97	–34.1	–58	–20.9
25-29	–310	–17.5	–573	–28.4	–110	–36.5	–94	–32.6
30-34	–259	–15.4	–308	–19.0	–106	–41.2	–78	–28.6
35-39	–238	–16.2	–133	–9.5	–95	–37.8	–75	–31.0
40-44	–147	–11.9	–114	–10.3	–61	–31.2	–48	–27.8
45-49	–96	–9.9	–7	–0.8	–43	–28.7	–16	–11.6
50-54	–28	–4.1	–19	–2.6	–34	–26.7	5	3.9
55-59	–25	–4.0	–26	–4.0	–19	–14.9	–13	–13.3
60-64	–2	–0.4	5	1.2	–8	–7.7	–22	–26.4
65-69	–2	–0.7	34	8.2	3	2.7	11	11.4
LaSalle								
15-19	–21	–4.3	1	0.1	–6	–10.9	–1	–1.6
20-24	–166	–32.6	–188	–34.7	–17	–27.2	–15	–27.5
25-29	–150	–30.1	–146	–27.8	–30	–45.2	–26	–33.1
30-34	–49	–10.6	2	0.4	–7	–16.4	–9	–17.2
35-39	28	7.4	2	0.4	–3	–6.4	12	25.0
40-44	48	13.9	16	4.3	–11	–25.1	–20	–36.7
45-49	39	11.6	17	5.5	–8	–15.5	–17	–23.8
50-54	25	10.0	32	12.4	–22	–35.1	–12	–23.8
55-59	5	2.5	–4	–2.0	–15	–39.9	9	32.9
60-64	23	14.0	5	2.6	2	7.8	7	53.2
65-69	25	15.7	19	13.8	11	49.9	15	102.7

APPENDIX I.—(Continued)

Parish and Age	Race and Sex							
	White				Nonwhite			
	Male		Female		Male		Female	
	No.	%	No.	%	No.	%	No.	%
Lincoln								
15-19	222	37.2	204	31.6	–69	–11.3	11	1.8
20-24	381	56.3	2	0.2	–1	–0.2	–20	–2.8
25-29	–82	–12.2	–219	–30.2	–260	–44.9	–292	–42.6
30-34	–125	–20.2	–106	–18.3	–252	–49.0	–298	–48.6
35-39	–101	–17.8	–12	–2.2	–216	–43.4	–192	–37.4
40-44	–46	–8.7	–10	–2.1	–139	–36.2	–172	–39.5
45-49	–3	–0.7	–39	–8.4	–75	–25.1	–40	–13.9
50-54	–33	–9.0	–3	–0.9	–53	–23.0	–41	–16.5
55-59	–33	–10.1	–2	–0.7	–37	–20.6	–31	–21.2
60-64	–22	–7.9	–16	–4.9	–38	–27.8	–11	–10.0
65-69	13	5.8	0	0.0	46	43.4	7	5.2
Livingston								
15-19	–125	–14.2	–160	–19.1	8	5.4	–10	–6.1
20-24	–325	–35.6	–271	–29.7	–8	–5.2	–27	–16.7
25-29	–306	–33.9	–176	–21.6	–23	–17.7	–22	–16.3
30-34	–105	–15.3	–70	–11.3	–10	–10.6	–32	–30.9
35-39	–41	–6.6	–31	–5.5	–10	–9.7	–8	–6.7
40-44	15	2.8	8	1.6	–16	–16.2	–7	–8.0
45-49	–3	–0.8	6	1.4	5	6.6	–2	–2.4
50-54	–15	–3.8	–34	–9.3	–12	–18.2	–20	–35.2
55-59	–18	–5.9	–10	–3.0	3	6.9	–3	–8.9
60-64	1	0.5	–26	–11.2	5	13.8	2	7.3
65-69	34	14.5	2	1.2	6	19.9	9	27.2
Madison								
15-19	–56	–20.7	–71	–24.7	–78	–14.6	–115	–20.0
20-24	–111	–36.4	–135	–42.5	–192	–35.1	–146	–24.6
25-29	–107	–36.6	–64	–23.1	–175	–34.8	–229	–39.6
30-34	–41	–17.0	–21	–7.7	–230	–47.4	–257	–44.2
35-39	–10	–4.2	–18	– 7.6	–298	–50.9	55	15.8
40-44	–11	–4.7	–24	–12.1	–253	–45.6	–113	–23.6
45-49	–26	–12.1	–3	–1.5	–119	–24.4	–124	–26.4
50-54	–23	–13.2	–47	–27.5	–68	–17.6	–30	–8.9
55-59	–25	–15.4	–12	–9.7	–66	–22.6	–39	–15.7
60-64	–23	–21.4	–4	–5.1	–36	–18.9	–32	–19.3
65-69	–12	–14.0	–13	–17.3	40	18.6	52	25.2
Morehouse								
15-19	93	16.7	130	24.2	–116	–14.7	–104	–12.1
20-24	80	13.7	62	9.6	–199	–27.6	–234	–27.5
25-29	89	14.7	84	13.7	–281	–40.9	–366	–43.2
30-34	170	34.3	274	75.9	–285	–41.9	–253	–33.3
35-39	140	28.3	101	51.1	–265	–41.0	–253	–33.3
40-44	78	17.0	41	8.6	–187	–33.7	–178	–26.7
45-49	28	7.1	–24	–6.0	–117	–21.9	–128	–23.6
50-54	–11	–3.6	27	9.5	–112	–24.2	–73	–17.9
55-59	10	3.8	18	7.8	–50	–16.1	–27	–9.5
60-64	42	20.6	24	11.0	–23	–10.6	–15	–7.3
65-69	54	32.8	39	22.7	58	26.5	25	11.2
Natchitoches								
15-19	–169	–15.0	41	3.6	–312	–27.6	–316	–27.6
20-24	–313	–27.6	–403	–32.9	–565	–51.3	–481	–44.0
25-29	–403	–37.0	–466	–40.6	–516	–54.5	–561	–51.1
30-34	–238	–26.5	–249	–26.0	–388	–49.7	–416	–46.5
35-39	–141	–16.7	–148	–17.5	–301	–39.6	–301	–38.4
40-44	–150	–19.4	–99	–13.3	–216	–37.7	–124	–20.3
45-49	–74	–11.7	–82	–13.6	–143	–27.9	–127	–22.7
50-54	–57	–11.1	–48	–9.0	–95	–22.6	–71	–16.8
55-59	–35	–7.5	–31	–7.0	–36	–10.9	–47	–14.1
60-64	–20	–5.3	–14	–4.0	–28	–11.2	–28	–10.9
65-69	47	15.6	–21	–5.8	–6	–2.0	14	4.6

APPENDIX I.—(Continued)

Parish and Age	Race and Sex							
	White				Nonwhite			
	Male		Female		Male		Female	
	No.	%	No.	%	No.	%	No.	%
Orleans								
15-19	96	9.0	1133	10.4	157	2.7	937	15.4
20-24	2513	18.9	3371	24.1	446	7.6	1397	20.2
25-29	2835	18.8	1705	10.3	889	14.5	1361	18.7
30-34	1192	8.6	–425	–2.7	1100	22.8	859	14.7
35-39	–423	–2.8	–897	–5.3	418	7.0	91	1.1
40-44	–371	–2.5	–582	–3.6	–49	–0.8	–303	–4.0
45-49	–553	–4.0	–746	–4.4	–10	–0.2	–125	–1.9
50-54	–689	–5.5	–410	–3.1	–203	–4.2	–326	–6.4
55-59	–718	–7.2	–955	–8.5	–210	–5.8	–164	–4.5
60-64	–695	–9.0	–408	–4.7	–27	–1.1	137	5.4
65-69	–520	–8.9	–142	–1.9	–31	–1.4	290	10.3
Ouachita								
15-19	29	1.7	322	20.5	42	5.3	104	12.5
20-24	–127	–6.7	480	26.1	86	11.2	188	19.9
25-29	183	9.9	367	19.3	–65	–7.7	34	3.3
30-34	383	25.1	75	3.9	–78	–9.5	–111	–9.9
35-39	162	9.4	48	2.5	–158	–17.0	–268	–21.4
40-44	98	5.8	36	2.1	–201	–22.1	–224	–20.6
45-49	29	1.9	76	6.0	–100	–12.7	–95	–10.3
50-54	43	3.6	70	6.0	–12	–2.0	–55	–8.8
55-59	50	5.4	69	7.6	–25	–5.2	31	7.5
60-64	53	7.0	76	10.9	1	0.2	68	26.3
65-69	54	9.3	161	27.9	117	39.9	165	50.1
Plaquemines								
15-19	–24	–7.0	–16	–4.9	–60	–17.3	–60	–17.9
20-24	59	17.4	74	24.2	–55	–20.6	–102	–32.0
25-29	111	37.3	53	17.1	–94	–33.5	–94	–34.4
30-34	57	19.4	19	6.1	–62	–26.2	–63	–28.3
35-39	–19	–4.9	–21	–6.0	–70	–28.3	–40	–19.9
40-44	–23	–6.2	1	0.3	–23	–21.3	–17	–13.8
45-49	–44	–13.5	–5	–2.3	–33	–21.3	–17	–13.8
50-54	22	10.7	1	0.5	–12	–12.7	–20	–23.0
55-59	–6	–3.8	–17	–12.0	–19	–22.9	–4	–4.4
60-64	10	8.0	3	3.1	–1	–1.7	–3	–4.5
65-69	7	7.8	–8	–9.1	13	16.5	–2	–2.4
Pointe Coupee								
15-19	–119	–20.9	–104	–19.1	–169	–25.7	–233	–30.7
20-24	–198	–34.3	–259	–41.9	–309	–48.3	–353	–49.5
25-29	–242	–39.3	–212	–37.2	–415	–62.3	–365	–50.5
30-34	–128	–27.3	–143	–28.1	–354	–54.0	–277	–46.7
35-39	–85	–19.1	–54	–13.8	–202	–40.6	–210	–38.8
40-44	–38	–10.2	–24	–7.1	–154	–36.2	–94	–24.5
45-49	–39	–11.3	–30	–9.4	–67	–19.8	–96	–26.3
50-54	–30	–11.6	–30	–9.4	–50	–19.8	–56	–19.6
55-59	–29	–12.9	–15	–6.3	–50	–22.4	–21	–9.5
60-64	6	3.4	–23	–12.8	–22	–11.6	–14	–8.2
65-69	–24	–15.0	–4	–2.9	63	30.7	–6	–2.3
Rapides								
15-19	–26	–1.3	358	17.8	–150	–12.2	–94	–6.9
20-24	–215	–9.8	104	4.4	–217	–18.9	–130	–9.5
25-29	–66	–3.0	72	2.9	–175	–15.1	–176	–12.6
30-34	315	15.3	151	2.3	–143	–13.6	–145	–11.6
35-39	313	15.8	195	9.1	–122	–11.1	–102	–8.2
40-44	230	12.5	230	12.2	–73	–7.5	24	2.3
45-49	205	13.3	57	3.3	4	0.5	4	0.5
50-54	137	10.0	81	5.8	35	5.0	37	5.0
55-59	119	10.0	126	10.7	48	8.4	7	1.3
60-64	77	8.0	93	9.6	59	14.7	30	7.4
65-69	109	15.0	83	10.4	150	40.4	130	28.7

APPENDIX I.—(Continued)

Parish and Age	Race and Sex							
	White				Nonwhite			
	Male		Female		Male		Female	
	No.	%	No.	%	No.	%	No.	%
Red River								
15-19	–166	–39.5	–202	–45.9	–138	–32.1	–185	–38.5
20-24	–276	–66.0	–289	–64.0	–240	–57.2	–271	–55.0
25-29	–235	–59.4	–244	–59.2	–290	–69.2	–255	–57.8
30-34	–164	–45.5	–149	–40.8	–190	–58.4	–200	–56.9
35-39	–138	–41.0	–118	–35.6	–193	–60.0	–129	–42.3
40-44	–100	–34.7	–61	–21.7	–55	–26.5	–85	–33.3
45-49	–42	–18.8	–47	–20.7	–56	–27.3	–83	–36.2
50-54	–46	–22.6	–42	–21.4	–64	–38.0	–46	–28.8
55-59	–31	–16.9	–17	–9.8	–43	–31.2	–37	–27.5
60-64	–18	–11.5	–41	–25.2	–22	–21.8	–35	–35.8
65-69	–6	–4.6	–11	–9.8	18	16.8	39	38.3
Richland								
15-19	–235	–24.8	–179	–20.0	–157	–22.1	–217	–30.1
20-24	–419	–46.2	–399	–40.8	–319	–50.2	–325	–46.2
25-29	–343	–39.2	–386	–40.5	–305	–54.6	–286	–46.5
30-34	–240	–31.7	–132	–19.4	–274	–55.0	–248	–44.3
35-39	–61	–10.0	–90	–14.9	–223	–42.7	–251	–41.2
40-44	–70	–12.7	–46	–8.9	–176	–39.2	–165	–33.7
45-49	–73	–14.5	–92	–18.9	–132	–32.1	–139	–32.2
50-54	–32	–8.6	–47	–12.1	–124	–38.4	–83	–27.2
55-59	–60	–17.6	–57	–17.5	–46	–17.6	–57	–24.6
60-64	–37	–12.4	–12	–4.9	–24	–12.9	–30	–17.8
65-69	–27	–12.9	–24	–11.8	2	1.0	29	16.2
Sabine								
15-19	–373	–34.3	–335	–33.3	–58	–23.3	–28	–12.2
20-24	–657	–61.8	–653	–57.5	–91	–36.9	–115	–42.3
25-29	–331	–55.1	–522	–48.1	–137	–54.6	–105	–41.4
30-34	–331	–40.0	–265	–32.5	–92	–46.4	–113	–50.7
35-39	–174	–24.1	–182	–25.3	–87	–49.0	–92	–40.0
40-44	–128	–19.5	–142	–22.0	–64	–38.1	–17	–11.0
45-49	–74	–14.0	–95	–16.9	–57	–35.7	–11	–7.1
50-54	–93	–20.1	–89	–19.1	–19	–14.4	–17	–16.9
55-59	–55	–12.7	–31	–7.9	0	0.0	12	17.7
60-64	–47	–13.6	–32	–9.9	–1	–1.9	0	0.0
65-69	51	19.8	3	1.4	10	12.8	10	16.8
St. Bernard								
15-19	2	0.5	57	19.8	–4	–6.1	–8	–10.6
20-24	63	19.9	114	36.0	–19	–25.1	4	5.7
25-29	160	49.1	168	53.2	–12	–17.7	–22	–31.7
30-34	130	59.1	118	47.3	–21	–32.8	–1	–1.2
35-39	125	52.2	89	34.1	–13	–25.7	–5	–9.4
40-44	88	39.1	43	17.5	–13	–26.1	13	32.1
45-49	66	29.3	25	11.4	5	12.6	–5	–12.2
50-54	37	20.8	11	6.6	–3	–7.3	–4	–10.7
55-59	23	15.3	–15	–9.4	1	2.5	11	50.3
60-64	26	26.1	7	7.7	–2	–12.7	–6	–23.0
65-69	15	15.2	–27	–25.0	7	31.4	6	29.1
St. Charles								
15-19	–91	–18.1	–67	–13.1	–20	–9.3	–33	–16.4
20-24	–141	–27.9	–195	–35.2	–64	–30.5	–51	–24.3
25-29	–91	–19.5	–174	–32.2	–42	–24.2	–53	–26.8
30-34	–58	–16.7	–36	–10.8	–33	–25.3	–29	–20.3
35-39	–31	–8.8	–38	–11.2	–19	–15.1	–19	–13.4
40-44	–13	–4.2	–6	–1.8	–7	–6.9	–2	–1.9
45-49	–30	–9.4	–23	–7.6	–5	–4.3	2	2.4
50-54	–10	–4.1	–13	–5.5	–11	–12.6	–6	–6.2
55-59	–13	–6.5	–13	–7.9	–9	–10.2	3	4.4
60-64	–4	–3.7	–3	–3.5	10	14.7	17	27.3
65-69	3	3.0	–7	–7.1	4	5.7	16	23.6

APPENDIX I.—(Continued)

Parish and Age	Race and Sex							
	White				Nonwhite			
	Male		Female		Male		Female	
	No.	%	No.	%	No.	%	No.	%
St. Helena								
15-19	–46	–18.6	–63	–27.2	–76	–23.5	–100	–26.6
20-24	–136	–51.8	–127	–52.0	–122	–44.4	–143	–44.9
25-29	–117	–44.2	–97	–42.8	–145	–55.6	–140	–53.8
30-34	–56	–29.5	–54	–27.5	–87	–45.6	–74	–40.1
35-39	–41	–25.5	–21	–13.1	–28	–17.0	–58	–28.4
40-44	–26	–14.5	–3	–1.9	–27	–16.0	–19	–14.0
45-49	–6	–4.3	–20	–15.5	–24	–21.8	–27	–23.1
50-54	–12	–9.8	–8	–7.3	–25	–30.5	–18	–19.6
55-59	–10	–9.4	–8	–7.7	0	0.0	–2	–3.6
60-64	–8	–10.8	–9	–11.2	–5	–9.5	–10	–17.5
65-69	14	22.3	–4	–5.2	15	19.0	18	27.8
St. James								
15-19	–98	–22.3	–116	–27.4	–96	–23.3	–132	–29.5
20-24	–199	–40.8	–212	–45.5	–189	–46.7	–192	–46.3
25-29	–229	–47.4	–251	–51.2	–199	–48.2	–212	–49.9
30-34	–169	–41.7	–157	–40.7	–172	–49.6	–130	–37.9
35-39	–90	–26.5	–78	–23.4	–130	–39.8	–167	–32.1
40-44	–44	–16.2	–49	–18.7	–54	–24.8	–24	–13.5
45-59	–57	–23.5	–12	–5.2	0	0.0	–21	–10.2
50-54	–54	–12.5	–28	–12.3	–33	–21.1	–2	–1.2
55-59	–17	–9.9	–20	–12.1	6	4.0	–10	–6.6
60-64	–11	–7.7	3	1.9	–21	–15.4	7	5.5
65-69	–17	–16.0	–17	–11.8	–12	–7.7	19	11.0
St. John The Baptist								
15-19	–60	–14.8	–82	–21.0	–62	–16.5	–56	–15.7
20-24	–135	–30.2	–222	–46.0	–38	–12.1	–106	–27.8
25-29	–167	–39.1	–203	–43.7	–122	–36.0	–130	–33.8
30-34	–109	–31.4	–137	–35.4	–92	–32.8	–78	–27.7
35-39	–116	–31.9	–75	–22.3	–51	–19.7	–24	–10.6
40-44	–20	–7.3	–45	–16.6	–11	–5.0	–12	–6.2
45-49	–32	–14.2	–10	–4.4	–5	–2.9	–31	–15.1
50-54	–41	–18.5	–39	–17.5	–9	–5.5	–4	–2.8
55-59	–6	–4.1	–22	–13.3	–9	–6.9	–2	–2.2
60-64	–24	–15.1	5	3.4	9	8.7	18	20.3
65-69	0	0.0	–3	–2.7	12	12.1	51	50.1
St. Landry								
15-19	–268	–12.4	–195	–9.1	–390	–17.4	–451	–19.3
20-24	–397	–18.4	–432	–18.7	–744	–39.0	–840	–37.6
25-29	–163	–9.0	–373	–18.3	–777	–45.5	–839	–43.7
30-34	–125	–7.2	–123	–7.2	–619	–42.8	–564	–37.0
35-39	–70	–4.3	–107	–6.6	–253	–20.5	–308	–23.4
40-44	–20	–2.1	–23	–1.8	–182	–19.8	–122	–13.3
45-49	–70	–6.0	–55	–4.6	–116	–14.8	–115	–14.8
50-54	–20	–2.1	–47	–4.7	–46	–8.0	–3	–0.5
55-59	–22	–2.9	4	0.5	–82	–16.0	–46	–9.7
60-64	–37	–6.3	8	1.4	19	5.8	17	5.0
65-69	15	3.5	18	3.9	–4	–1.1	58	14.2
St. Martin								
15-19	–222	–22.7	–263	–25.7	–74	–12.5	–139	–21.4
20-24	–355	–36.4	–418	–39.8	–193	–36.9	–226	–36.7
25-29	–270	–31.8	–330	–35.8	–209	–39.2	–205	–39.8
30-34	–226	–29.7	–218	–27.8	–210	–43.6	–184	–39.5
35-39	–141	–19.7	–85	–13.8	–86	–21.8	–41	–12.0
40-44	–56	–9.7	–100	–16.5	–62	–24.0	–50	–21.6
45-49	–74	–14.1	–52	–10.6	–58	–25.1	–40	–17.8
50-54	–21	–5.4	–24	–6.3	–32	–20.8	–13	–9.7
55-59	–27	–7.5	–66	–18.3	–25	–16.7	–25	–17.0
60-64	–29	–11.9	9	3.6	14	12.9	19	18.3
65-69	2	0.8	5	2.4	–2	–1.4	–9	–6.9

APPENDIX I.—(Continued)

Parish and Age	Race and Sex							
	White				Nonwhite			
	Male		Female		Male		Female	
	No.	%	No.	%	No.	%	No.	%
St. Mary								
15-19	–9	–1.1	73	9.0	–141	–20.0	–170	–23.4
20-24	42	5.1	–7	–0.8	–295	–39.6	–318	–40.1
25-29	–16	–1.7	–41	–4.5	–311	–43.8	–297	–41.4
30-34	–43	–5.2	16	2.0	–253	–41.8	–199	–31.8
35-39	13	1.6	–31	–3.9	–180	–32.4	–126	–31.6
40-44	37	5.3	13	2.0	–94	–21.9	–71	–16.5
45-49	34	5.6	45	8.6	–18	–4.6	–27	–7.5
50-54	7	1.7	41	9.8	–54	–16.7	–30	–9.6
55-59	10	3.0	11	3.0	–20	–7.5	–21	–7.7
60-64	20	7.0	27	9.4	–1	–0.4	5	2.2
65-69	28	11.1	35	12.3	8	3.2	41	15.1
St. Tammany								
15-19	2	0.3	–67	–8.5	–37	–9.8	–45	–11.1
20-24	–277	–31.9	–207	–32.8	–123	–33.7	–107	–26.7
25-29	–312	–33.0	–211	–25.0	–55	–18.1	–90	–25.6
30-34	–68	–10.5	–24	–3.8	–27	–10.9	–58	–18.1
35-39	–18	–2.9	70	12.0	–59	–19.5	–53	–15.3
40-44	50	9.3	63	11.2	–44	–17.3	–34	–14.0
45-49	62	13.1	–131	–18.3	–12	–5.6	8	3.8
50-54	43	9.1	41	8.3	–24	–14.6	–28	–16.2
55-59	51	12.1	38	9.4	–15	–9.6	12	9.9
60-64	40	12.2	58	17.7	7	6.4	–11	–8.1
65-69	88	31.6	70	24.5	14	11.0	30	28.3
Tangipahoa								
15-19	72	4.7	99	6.4	–73	–9.7	10	1.3
20-24	–179	–11.0	–375	–22.1	–185	–25.5	–231	–26.1
25-29	–357	–21.5	–349	–20.9	–194	–26.5	–200	–23.8
30-34	–114	–8.7	–80	–5.8	–211	–33.3	–178	–25.5
35-39	–29	–2.3	–19	–1.4	–132	–21.5	–127	–18.3
40-44	129	11.3	59	5.1	–10	–1.9	–16	–3.1
45-49	61	5.9	–7	–0.7	–51	–10.8	–46	–9.5
50-54	70	9.6	25	3.2	8	2.2	–19	–5.2
55-59	30	4.3	43	6.7	–6	–2.0	–10	–3.5
60-64	65	12.5	10	1.8	–15	–6.8	4	2.2
65-69	84	17.3	59	11.8	62	27.3	83	43.1
Tensas								
15-19	–66	–27.5	–57	–23.4	–165	–31.5	–205	–37.7
20-24	–121	–48.0	–118	–24.4	–274	–57.0	–294	–51.1
25-29	–131	–46.2	–63	–26.1	–349	–67.4	–307	–55.7
30-34	–56	–26.6	–34	–15.9	–252	–58.3	–242	–52.0
35-39	–34	–16.1	–23	–12.7	–181	–46.3	–213	–43.0
40-44	–32	–18.5	–43	–24.7	–155	–41.9	–124	–29.8
45-49	–19	–12.7	–43	–27.9	–100	–30.5	–106	–29.9
50-54	–26	–20.4	–10	–9.2	–79	–30.2	–69	–24.0
55-59	–20	–17.6	–11	–3.0	–25	–16.5	–33	–21.0
60-64	–15	–17.9	–2	–3.0	–25	–16.5	–33	–21.9
65-69	–2	–2.8	3	5.2	–26	–11.8	–21	–8.7
Terrebonne								
15-19	–149	–10.1	–100	–6.9	–78	–14.9	–110	–18.7
20-24	–104	–6.9	–204	–13.1	–136	–28.0	–182	–31.0
25-29	12	0.9	–158	–10.7	–197	–35.5	–190	–33.9
30-34	–9	–0.8	–37	–3.0	–175	–39.6	–118	–28.5
35-39	–91	–7.3	–81	–7.0	–65	–16.0	–21	–6.0
40-44	–5	–0.5	–59	–6.4	–21	–8.0	–23	–8.4
45-49	–38	–4.5	–2	–0.3	–270	–56.0	–7	–2.8
50-54	0	0.0	–4	–0.6	–3	–1.7	–27	–15.0
55-59	8	1.7	38	7.7	12	6.8	–2	–1.3
60-64	–10	–2.5	–5	–1.4	6	4.3	9	7.8
65-69	6	2.0	33	10.7	25	17.0	14	9.0

APPENDIX I.—(Continued)

Parish and Age	Race and Sex							
	White				Nonwhite			
	Male		Female		Male		Female	
	No.	%	No.	%	No.	%	No.	%
Union								
15-19	-177	-24.7	-184	-26.2	-91	-21.2	-73	-17.3
20-24	-340	-47.3	-378	-52.8	-139	-34.2	-224	-49.8
25-29	-392	-49.5	-338	-44.7	-238	-57.1	-214	-46.6
30-34	-255	-39.8	-160	-26.2	-173	-50.2	-161	-47.3
35-39	-120	-21.9	-119	-21.7	-88	-32.1	-60	-22.6
40-44	-38	-8.0	-64	-14.8	-52	-26.6	-79	-35.7
45-49	-48	-11.6	-20	-4.7	-31	-16.9	-28	-15.2
50-54	-34	-9.7	-38	-11.2	-29	-18.5	-15	-9.9
55-59	4	1.3	-33	-9.9	1	0.7	1	0.8
60-64	3	0.9	-19	-6.8	-15	-19.2	-8	-10.8
65-69	23	10.1	-2	-1.0	13	14.6	16	23.1
Vermilion								
15-19	-391	-21.1	-454	-24.0	-79	-26.1	-54	-16.7
20-24	-715	-38.8	-734	-37.8	-104	-36.1	-102	-33.7
25-29	-607	-35.1	-588	-33.5	-107	-45.6	-126	-42.0
30-34	-411	-26.8	-382	-24.8	-100	-46.4	-106	-42.0
35-39	-181	-12.9	-176	-12.6	-71	-31.8	-51	-26.0
40-44	-114	-8.7	-152	-12.4	-49	-29.5	-22	-14.2
45-49	-124	-11.1	-121	-11.4	-22	-18.8	-12	-9.2
50-54	-25	-3.0	-38	-4.7	-19	-22.1	-4	-4.3
55-59	-57	-8.2	-33	-4.7	-5	-5.9	-10	-15.0
60-64	-33	-6.3	-13	-2.4	7	13.4	-9	-16.1
65-69	18	4.3	-4	-0.9	10	15.1	5	9.0
Vernon								
15-19	-208	-22.6	-229	-25.0	-27	-22.0	-17	-17.2
20-24	-477	-52.3	-459	-47.2	-42	-44.7	-39	-33.1
25-29	-451	-49.8	-342	-38.6	-42	-41.3	-48	-34.4
30-34	-224	-30.5	-140	-20.0	-26	-34.9	-25	-28.5
35-39	-88	-13.6	-29	-4.8	-24	-28.5	-13	-11.2
40-44	-7	-1.4	-25	-4.4	-27	-31.7	-11	-13.2
45-49	-13	-2.5	8	1.7	-12	-14.8	-7	-8.5
50-54	-44	-10.1	-58	-12.8	-17	-22.3	-23	-28.4
55-59	16	4.3	-11	-2.8	-13	-19.5	-8	-17.2
60-64	4	1.2	-20	-6.4	-10	-17.9	-7	-17.4
65-69	18	6.0	16	6.0	13	21.7	16	37.5
Washington								
15-19	-257	-20.1	-189	-15.6	-79	-14.5	-29	-4.8
20-24	-386	-29.9	-299	-23.4	-107	-21.7	-156	-24.3
25-29	-287	-22.5	-258	-19.9	-126	-24.9	-94	-15.8
30-34	-106	-10.1	-128	-11.6	-88	-23.4	-121	-26.0
35-39	-70	-6.6	-94	-9.0	-80	-18.6	-125	-23.1
40-44	-16	-1.8	-82	-9.1	-52	-13.3	-69	-16.6
45-49	-1	-0.2	-20	-2.6	-52	-13.6	-45	-12.0
50-54	-10	-1.5	-58	-8.6	-35	-12.8	-25	-9.7
55-59	-35	-6.6	-19	-3.8	3	1.3	5	2.5
60-64	30	6.8	-18	-4.4	6	4.4	23	18.0
65-69	8	2.3	28	9.0	50	34.5	37	32.3
Webster								
15-19	-93	-11.2	-27	-3.1	-144	-18.2	-164	-19.3
20-24	-172	-18.4	-60	-6.6	-234	-35.2	-258	-33.8
25-29	-79	-8.5	-13	-1.3	-285	-41.7	-318	-41.1
30-34	-65	-6.7	-103	-9.9	-290	-46.6	-338	-43.6
35-39	-147	-14.4	-65	-6.8	-234	-38.7	-226	-31.7
40-44	-62	-7.4	-78	-9.6	-154	-28.2	-132	-25.9
45-49	-83	-11.8	-55	-8.7	-79	-19.4	-69	-16.9
50-54	-33	-5.9	15	3.2	-74	-23.6	-52	-16.7
55-59	-13	-2.9	23	5.3	-43	-18.7	-33	-15.6
60-64	-1	-0.4	19	5.8	-27	-16.1	-26	-17.6
65-69	47	17.2	50	18.2	73	44.3	66	38.6

APPENDIX I.—(Continued)

Parish and Age	Race and Sex							
	White				Nonwhite			
	Male		Female		Male		Female	
	No.	%	No.	%	No.	%	No.	%
West Baton Rouge								
15-19	–30	–12.9	18	9.0	–50	–16.2	–86	–27.7
20-24	–44	–18.2	–24	–9.7	–72	–26.7	–110	–32.9
25-29	–6	–2.5	–14	–5.5	–147	–43.7	–135	–39.8
30-34	4	2.2	14	5.5	–118	–43.2	–90	–30.8
35-39	28	14.3	5	3.1	–108	–39.3	–113	–39.7
40-44	10	7.6	13	8.3	–56	–24.9	–29	–12.8
45-49	20	14.3	–7	–5.5	–13	–7.4	–49	–20.8
50-54	8	7.3	–2	–2.1	–14	–8.0	–29	–19.2
55-59	–9	–8.3	–5	–4.3	–42	–24.7	–6	–4.2
60-64	9	9.8	–2	–2.3	–14	–11.5	–1	–1.1
65-69	–14	–18.9	–8	–11.0	8	6.3	14	12.7
West Carroll								
15-19	–175	–19.8	–282	–29.9	–53	–24.7	–90	–37.6
20-24	–476	–52.1	–508	–53.2	–89	–50.4	–106	–47.3
25-29	–486	–56.1	–421	–48.9	–93	–55.3	–108	–56.1
30-34	–264	–38.9	–218	–32.6	–141	–70.4	–124	–62.0
35-39	–151	–23.7	–118	–20.0	–71	–45.4	–97	–51.2
40-44	–114	–20.1	–61	–13.1	–110	–60.1	–89	–52.0
45-49	–67	–16.1	–79	–19.3	–72	–50.5	–61	–47.7
50-54	–46	–13.2	–25	–8.5	–69	–51.7	–28	–29.2
55-59	–36	–12.4	–48	–18.3	–29	–32.7	–10	–14.1
60-64	–54	–20.6	–49	–19.3	–11	–21.4	–15	–27.9
65-69	–11	–4.8	12	7.4	11	19.1	17	37.4
West Feliciana								
15-19	55	70.2	–15	–21.6	10	2.4	–161	–35.2
20-24	182	203.1	–23	–26.2	178	47.5	–253	–56.9
25-29	142	102.8	–31	–33.5	46	10.2	–170	–54.6
30-34	–43	–20.0	–24	–31.8	–213	–36.5	–156	–55.6
35-39	–79	–31.7	15	21.7	–301	–51.4	–99	–35.2
40-44	–70	–31.8	–16	–18.1	–246	–48.0	–61	–28.5
45-49	–31	–17.4	–5	–8.0	–190	–47.4	–67	–37.4
50-54	–27	–20.4	4	8.5	–116	–45.6	–11	–8.1
55-59	–15	–16.4	10	20.7	–50	–28.2	–39	–31.7
60-64	–15	–21.0	5	10.1	–35	–24.0	–20	–20.6
65-69	–15	–23.1	4	11.6	–22	–15.4	–7	–5.7
Winn								
15-19	–200	–29.0	–187	–29.8	–18	–9.8	–39	–16.2
20-24	–349	–50.1	–330	–47.4	–59	–30.0	–34	–15.2
25-29	–362	–50.5	–283	–43.1	–70	–35.1	–81	–33.3
30-34	–211	–35.7	–128	–24.3	–45	–27.3	–72	–35.9
35-39	–116	–21.2	–105	–21.0	–30	–19.5	–39	–19.7
40-44	–28	–6.5	–59	–13.2	–49	–29.7	–31	–20.1
45-49	–63	–16.6	–69	–17.6	–1	–0.7	–9	–5.5
50-54	–21	–7.0	–33	–9.9	–18	–14.8	–15	–12.1
55-59	–21	–7.1	8	2.6	0	0.0	2	2.8
60-64	8	3.5	1	0.2	3	3.4	10	18.3
65-69	25	11.9	–2	–0.8	33	55.3	41	86.0

APPENDIX II.—Net Migration by Age, Race, and Sex for Louisiana Parishes, 1950-1960

Parish and Age	Race and Sex							
	White				Nonwhite			
	Male		Female		Male		Female	
	No.	%	No.	%	No.	%	No.	%
Acadia								
15-19	–394	–19.4	–433	–20.7	–77	–13.8	–78	–14.5
20-24	–775	–39.6	–672	–34.5	–146	–31.9	–195	–36.8
25-29	–544	–31.3	–643	–35.5	–174	–42.4	–179	–37.5
30-34	–329	–21.0	–296	–19.1	–90	–29.4	–150	–37.4
35-39	–178	–13.4	–210	–14.4	–49	–17.8	–36	–12.2
40-44	–119	–9.0	–101	–7.6	–28	–13.0	–34	–13.0
45-49	–118	–9.1	–145	–11.2	–19	–8.0	–17	–6.3
50-54	–92	–8.3	–66	–5.7	–23	–11.8	–24	–11.1
55-59	–31	–3.2	34	3.3	10	7.0	3	1.6
60-64	–15	–2.3	–11	–1.4	6	4.6	26	19.8
65-69	–10	–2.0	11	1.9	11	9.8	15	10.9
Allen								
15-19	–215	–26.4	–186	–22.0	–41	–14.6	–49	–17.4
20-24	–238	–37.0	–241	–33.5	–91	–41.3	–93	–42.1
25-29	–163	–28.4	–209	–33.2	–78	–43.2	–74	–36.4
30-34	–86	–16.9	–118	–21.0	–3	–2.5	–27	–16.8
35-39	–46	–9.1	–93	–18.4	–11	–8.4	–29	–18.8
40-44	–68	–13.2	–28	–5.7	–16	–14.0	–13	–9.7
45-49	–186	–12.9	–34	–7.5	–33	–23.9	–23	–15.3
50-54	–241	–4.6	–28	–6.8	1	1.4	–4	–3.6
55-59	–209	–0.8	–17	–4.4	–17	–16.1	–7	–6.7
60-64	–118	–4.4	6	2.3	–1	–1.1	9	11.7
65-69	–93	2.9	–36	–13.0	–6	–7.2	9	12.5
Ascension								
15-19	–35	–4.4	4	0.5	–63	–12.7	–91	–18.2
20-24	–126	–19.0	–68	–10.2	–147	–38.6	–94	–23.5
25-29	–9	–1.6	–37	–5.9	–98	–30.9	–121	–35.3
30-34	89	16.7	76	14.7	–69	–27.4	–62	–22.3
35-39	76	13.9	24	4.2	–17	–8.7	–14	–5.5
40-44	0	0.0	38	7.6	–8	–4.6	–15	–6.3
45-49	42	9.3	43	10.5	22	12.2	–12	–6.5
50-54	44	10.9	44	10.9	–18	–10.9	–17	–9.4
55-59	–2	–0.5	6	1.9	–11	–6.4	1	0.6
60-64	11	4.0	28	8.7	27	27.3	–6	–4.4
65-69	21	10.2	–6	–2.1	12	9.7	17	9.6
Assumption								
15-19	–78	–14.7	–85	–15.3	–102	–20.5	–137	–26.2
20-24	–171	–35.4	–211	–42.2	–102	–30.8	–218	–51.0
25-29	–143	–33.1	–143	–31.9	–160	–52.0	–156	–52.6
30-34	–23	–7.0	–56	–16.2	–89	–38.8	–50	–20.4
35-39	–44	–12.6	–21	–6.4	–34	–18.1	–62	–23.9
40-44	–11	–3.5	–19	–5.9	–26	–15.2	–23	–14.2
45-49	–48	–12.9	–20	–5.9	–16	–9.5	–13	–7.7
50-54	–41	–14.7	–29	–11.1	–27	–18.2	–26	–18.3
55-59	–2	–0.7	–5	–1.9	15	13.3	–1	–0.1
60-64	13	7.2	12	5.1	4	4.4	–7	–6.0
65-69	3	1.9	–18	–10.6	–30	–20.6	–15	–10.3
Avoyelles								
15-19	–311	–21.4	–439	–28.8	–83	–13.3	–121	–19.5
20-24	–757	–55.2	–798	–56.4	–240	–42.9	–235	–42.9
25-29	–556	–47.0	–529	–44.1	–271	–53.2	–251	–48.4
30-34	–213	–22.9	–184	–19.0	–151	–42.9	–124	–31.1
35-39	–231	–23.5	–170	–17.0	–77	–26.3	–32	–11.9
40-44	–140	–14.0	–118	–11.3	0	0.0	–8	–3.5
45-49	–84	–8.4	–25	–2.8	–41	–19.1	–29	–11.3
50-54	–41	–4.8	–36	–4.3	–6	–2.9	–13	–5.8
55-59	–20	–2.7	–2	–0.3	–24	–13.3	1	0.1
60-64	9	1.5	28	4.8	19	14.4	18	12.3
65-69	–1	–0.2	16	3.0	2	1.8	9	6.0

APPENDIX II.—(Continued)

Parish and Age	Race and Sex							
	White				Nonwhite			
	Male		Female		Male		Female	
	No.	%	No.	%	No.	%	No.	%
Beauregard								
15-19	–124	–15.2	–209	–24.3	56	31.9	–17	–10.6
20-24	–272	–38.9	–414	–52.1	99	87.6	–21	–16.4
25-29	–238	–37.5	–245	–39.6	16	14.7	–1	–1.0
30-34	–21	–5.2	–46	–9.0	36	42.4	–4	–3.3
35-39	–21	–4.7	–30	–6.1	–19	–17.8	–13	–11.8
40-44	–40	–8.3	–25	–4.9	4	6.2	1	1.2
45-49	–22	–4.4	–70	–12.8	–3	–3.6	14	16.4
50-54	–59	–12.0	–40	–9.2	12	18.2	17	18.7
55-59	–35	–8.8	–14	–3.9	–4	–6.2	0	0.0
60-64	–4	–1.3	14	5.0	2	4.1	–8	–12.6
65-69	15	6.7	8	2.8	16	27.1	22	35.1
Bienville								
15-19	–89	–21.3	–150	–31.3	–124	–21.3	–177	–29.9
20-24	–268	–58.5	–283	–63.1	–297	–52.6	–351	–60.6
25-29	–282	–64.0	–194	–50.6	–298	–65.0	–348	–65.2
30-34	–54	–22.2	–43	–18.6	–178	–52.5	–143	–42.4
35-39	–18	–8.1	–23	–9.3	–76	–35.0	–72	–28.2
40-44	–42	–15.5	–32	–9.7	–74	–30.6	–52	–18.7
45-49	–32	–9.9	–44	–12.0	–39	–18.5	–39	–15.3
50-54	–24	–6.6	–23	–7.2	–14	–7.0	–34	–14.0
55-59	14	5.2	10	3.4	–5	–2.5	0	0.0
60-64	–1	–0.2	–27	–10.5	14	10.5	1	0.4
65-69	7	3.5	–25	–10.7	17	13.8	15	10.3
Bossier								
15-19	382	33.5	385	34.3	–209	–23.6	–215	–23.9
20-24	1648	223.0	1248	158.5	–172	–24.9	–286	–40.2
25-29	1071	91.5	1185	151.9	–308	–51.1	–295	–44.3
30-34	–550	–24.7	465	38.6	–234	–45.1	–137	–27.1
35-39	–148	–8.0	44	2.7	–89	–25.8	–102	–25.3
40-44	–132	–8.3	1	0.1	–20	–6.7	–32	–8.4
45-49	–19	–2.0	77	9.0	–18	–6.0	–9	–2.5
50-54	–43	–5.7	91	16.0	–38	–11.8	–56	–15.9
55-59	41	8.0	57	12.0	–16	–4.9	6	2.0
60-64	9	2.4	52	15.8	15	6.6	–11	–4.5
65-69	28	11.8	46	17.6	42	18.5	35	14.2
Caddo								
15-19	–301	–6.9	316	6.9	–231	–6.5	–354	–9.9
20-24	106	3.0	1218	33.2	–492	–8.7	–156	–5.1
25-29	1458	47.5	1185	31.1	–344	–15.0	–170	–6.1
30-34	998	23.4	18	0.3	–226	–10.6	–388	–12.4
35-39	130	2.5	13	–0.2	–131	–6.6	–197	–7.4
40-44	41	0.9	100	2.1	–37	–2.1	–112	–4.6
45-49	140	3.4	48	1.1	–45	–2.5	–87	–3.8
50-54	73	2.0	119	3.0	–32	–2.0	–4	–0.2
55-59	21	0.7	128	3.6	–2	–0.2	18	1.0
60-64	–63	–2.5	158	5.7	105	9.6	46	3.4
65-69	164	8.7	256	11.6	213	21.1	280	22.8
Calcasieu								
15-19	637	18.0	749	20.2	104	9.3	124	11.3
20-24	1934	67.2	1710	59.1	284	33.6	249	26.8
25-29	2184	88.1	1656	59.7	322	46.4	175	18.6
30-34	1627	59.7	1182	37.1	137	17.2	52	4.9
35-39	1027	33.2	812	24.7	70	8.8	–22	–2.4
40-44	834	29.2	490	16.9	16	2.1	83	11.8
45-49	336	12.1	296	11.6	61	9.9	33	4.8
50-54	187	8.0	252	11.2	42	8.5	38	7.7
55-59	72	4.0	109	6.4	–19	–3.9	–12	–2.7
60-64	51	4.1	116	9.5	–1	–0.4	11	3.4
65-69	26	2.9	70	7.0	–16	–5.0	10	3.2

APPENDIX II.—(Continued)

Parish and Age	Race and Sex							
	White				Nonwhite			
	Male		Female		Male		Female	
	No.	%	No.	%	No.	%	No.	%
Caldwell								
15-19	–90	–23.8	–146	–37.5	–49	–30.9	–61	–31.9
20-24	–188	–57.5	–240	–62.1	–89	–62.7	–100	–64.2
25-29	–202	–62.9	–150	–53.3	–106	–73.0	–88	–58.2
30-34	–79	–36.6	–92	–38.2	–61	–60.9	–56	–51.3
35-39	–80	–35.1	–45	–18.5	–14	–23.9	–18	–24.4
40-44	–56	–23.3	–39	–17.4	–4	–6.6	–7	–9.1
45-49	–29	–12.7	–28	–11.7	–15	–22.5	–9	–10.9
50-54	–13	–6.0	–12	–5.9	–17	–24.1	–24	–32.1
55-59	–7	–3.8	–2	–0.9	–11	–17.1	–11	–17.4
60-64	–7	–4.5	1	0.7	–8	–15.8	–17	–30.3
65-69	16	11.6	–4	–2.3	–3	–6.1	–7	–13.8
Cameron								
15-19	–70	–22.3	–66	–21.7	–11	–34.2	–8	–27.0
20-24	–69	–25.9	–46	–17.9	–12	–41.3	–16	–48.2
25-29	4	1.6	–20	–8.4	–13	–36.0	–4	–17.7
30-34	–8	–3.3	–11	–4.8	–17	–50.1	–7	–34.5
35-39	2	0.9	–10	–4.9	–1	–4.5	–4	–24.4
40-44	1	0.6	–13	–7.1	–9	–37.3	–8	–52.3
45-49	–26	–11.8	–7	–3.4	–10	–63.5	–11	–60.5
50-54	–5	–2.5	–13	–7.0	–5	–28.1	–3	–28.0
55-59	–11	–6.3	–4	–2.7	–5	–38.6	–6	–51.0
60-64	–22	–16.3	–25	–19.8	–2	–15.0	–3	–45.8
65-69	–10	–12.0	–14	–16.1	0	0.0	–2	–20.1
Catahoula								
15-19	–116	–26.2	–149	–31.5	–71	–30.8	–68	–27.7
20-24	–248	–56.8	–238	–52.2	–115	–56.6	–120	–57.3
25-29	–178	–47.2	–141	–38.0	–107	–61.5	–104	–54.7
30-34	–39	–14.8	–37	–16.6	–64	–54.7	–60	–40.3
35-39	–41	–18.2	–27	–11.7	–31	–34.2	–23	–17.9
40-44	–35	–15.6	–17	–6.8	4	4.7	–32	–26.8
45-49	–48	–17.2	–33	–13.7	–5	–4.6	5	3.8
50-54	–32	–13.2	–30	–14.1	–2	–1.6	–21	–18.1
55-59	–18	–8.3	–18	–9.7	–23	–27.7	–14	–14.3
60-64	–11	–6.9	–6	–4.7	8	11.9	–2	–3.5
65-69	3	2.6	11	8.8	7	11.8	20	26.8
Claiborne								
15-19	–180	–35.5	–203	–39.9	–278	–35.4	–279	–34.9
20-24	–347	–69.0	–332	–65.6	–451	–66.1	–469	–64.4
25-29	–252	–51.7	–210	–44.1	–489	–72.1	–460	–67.2
30-34	–134	–36.4	–116	–31.2	–282	–64.7	–274	–52.8
35-39	–153	–35.4	–157	–36.6	–142	–43.9	–161	–37.7
40-44	–133	–33.7	–125	–26.3	–70	–24.3	–81	–22.7
45-49	–113	–26.6	–93	–22.6	–78	–24.2	–41	–12.8
50-54	–84	–22.6	–63	–14.7	–29	–11.0	–73	–22.6
55-59	–69	–19.1	–19	–5.1	–54	–20.0	–39	–13.6
60-64	–14	–4.6	–21	–7.0	9	4.7	–18	–8.1
65-69	2	0.7	1	0.3	7	22.9	–1	–0.5
Concordia								
15-19	68	21.2	82	24.3	–82	–16.8	–85	18.0
20-24	–34	–12.6	84	28.5	–186	–48.2	–193	–45.5
25-29	150	62.3	207	83.8	–173	–53.8	–181	–43.8
30-34	209	92.1	223	101.6	–65	–31.3	–68	–21.2
35-39	192	89.1	121	48.4	–26	–13.6	–5	–2.3
40-44	135	64.4	120	55.4	1	0.4	–17	–6.7
45-49	142	75.9	102	58.0	13	6.8	–20	–7.0
50-54	74	39.5	32	18.1	–4	–1.9	17	7.5
55-59	41	24.5	14	8.8	–10	–4.8	10	4.7
60-64	24	17.5	16	12.7	23	16.8	–6	–3.3
65-69	8	8.8	15	16.0	19	11.6	37	20.8

APPENDIX II.—(Continued)

Parish and Age	Race and Sex							
	White				Nonwhite			
	Male		Female		Male		Female	
	No.	%	No.	%	No.	%	No.	%
DeSoto								
15-19	–99	–20.6	–113	–22.2	–146	–16.1	–118	–13.7
20-24	–249	–54.6	–270	–53.6	–341	–50.9	–450	–56.3
25-29	–189	–46.0	–163	–40.8	–374	–60.0	–378	–55.2
30-34	–32	–11.6	–18	–5.2	–113	–32.4	–158	–32.8
35-39	–5	–1.9	–8	–2.5	–95	–28.1	–76	–18.4
40-44	1	0.2	–44	–11.5	–8	–2.9	–44	–11.4
45-49	–10	–3.0	–9	–2.5	2	0.6	7	2.0
50-54	7	2.1	–15	–4.3	–19	–6.5	–7	–1.8
55-59	6	2.1	–15	–4.7	–18	–6.0	15	4.9
60-64	–7	–3.2	40	15.9	51	25.3	9	3.6
65-69	25	11.2	–17	–5.5	40	16.2	67	26.0
East Baton Rouge								
15-19	1175	24.0	1682	34.0	878	35.9	1038	39.6
20-24	2664	81.5	2909	84.3	817	44.1	1227	58.1
25-29	1874	50.3	1613	39.5	92	4.9	39	1.7
30-34	–206	–3.4	163	2.7	–210	–9.7	–337	–12.2
35-39	175	3.0	401	6.9	–123	–5.9	–90	–3.7
40-44	351	7.3	251	5.3	72	4.2	8	0.4
45-49	271	6.6	271	6.7	–13	–0.8	–44	–2.4
50-54	159	4.8	277	8.3	37	2.7	105	6.6
55-59	100	3.9	176	6.7	36	3.2	23	1.9
60-64	8	0.4	105	5.3	102	13.8	165	18.7
65-69	14	1.1	150	9.7	114	16.5	215	26.2
East Carroll								
15-19	–201	–47.2	–164	–42.1	–145	–25.6	–207	–34.8
20-24	–230	–63.2	–182	–54.2	–276	–62.3	–272	–58.6
25-29	–167	–56.5	–133	–43.4	–254	–66.5	–226	–54.5
30-34	–32	–15.2	–36	–15.1	–165	–58.8	–153	–43.6
35-39	–44	–18.2	–31	–15.8	–78	–37.1	–83	–28.4
40-44	–55	–28.9	–39	–18.9	–41	–21.1	–63	–22.4
45-49	–52	–24.6	–54	–25.5	–41	–18.6	–67	–23.8
50-54	–47	–23.9	–42	–24.6	–74	–33.3	–11	–4.1
55-59	–24	–16.4	–11	–8.2	–22	–11.0	–54	–21.5
60-64	–15	–14.6	–18	–17.5	–1	–0.6	–35	–15.9
65-69	–23	–25.7	–3	–3.3	6	3.1	24	11.7
East Feliciana								
15-19	59	28.6	17	7.5	–97	–16.8	–183	–28.4
20-24	47	24.1	–8	–4.0	–223	–41.8	–248	–46.4
25-29	31	14.8	20	11.3	–164	–34.8	–210	–43.5
30-34	25	9.5	37	17.1	–99	–22.8	–59	–15.7
35-39	55	21.7	49	18.6	–23	–6.8	–44	–14.5
40-44	82	28.1	94	36.3	–11	–3.5	–55	–18.0
45-49	88	27.7	77	24.7	7	2.3	–8	–2.4
50-54	67	19.2	34	10.3	–11	–3.5	14	4.5
55-59	90	27.3	58	17.1	7	2.4	–29	–10.1
60-64	56	24.4	20	6.1	–3	–1.5	12	5.9
65-69	23	12.8	–5	–1.9	0	0.0	–8	–3.4
Evangeline								
15-19	–335	–25.3	–391	–29.8	–95	–17.2	–84	–14.5
20-24	–576	–52.5	–606	–51.2	–167	–38.9	–171	–32.9
25-29	–417	–41.3	–430	–41.1	–175	–41.7	–158	–39.3
30-34	–244	–27.6	–172	–18.8	–136	–45.6	–105	–32.9
35-39	–161	–17.9	–159	–18.7	–32	–16.0	–57	–21.9
40-44	–150	–16.2	–143	–15.5	–21	–11.1	–2	–0.8
45-49	–78	–8.8	–68	–7.8	–39	–21.1	–4	–2.2
50-54	–82	–10.2	–50	–6.9	2	1.5	–6	–5.4
55-59	–44	–6.6	–34	–4.8	–4	–3.1	–12	–10.3
60-64	4	0.8	–2	–0.3	–2	–2.1	0	0.0
65-69	–10	–2.6	2	0.4	7	8.9	–9	–11.3

APPENDIX II.—(Continued)

Parish and Age	Race and Sex							
	White				Nonwhite			
	Male		Female		Male		Female	
	No.	%	No.	%	No.	%	No.	%
Franklin								
15-19	–409	–36.8	–482	–42.0	–120	–16.7	–198	–28.1
20-24	–685	–66.2	–691	–64.2	–256	–53.3	–334	–56.5
25-29	–538	–60.9	–503	–54.6	–332	–65.3	–306	–55.4
30-34	–233	–36.3	–177	–29.5	–148	–44.1	–169	–40.2
35-39	–130	–24.6	–171	–27.6	–92	–37.3	–75	–21.9
40-44	–168	–28.3	–160	–24.1	–81	–33.4	–63	–22.0
45-49	–120	–18.9	–108	–17.6	–40	–15.7	–75	–23.6
50-54	–90	–14.8	–58	–10.7	–13	–5.9	7	2.8
55-59	–71	–15.2	–52	–11.2	–43	–17.9	–40	–17.1
60-64	–40	–11.7	–17	–5.7	5	2.9	–20	–12.1
65-69	13	5.6	–10	–3.4	–11	–6.9	9	5.2
Grant								
15-19	–142	–23.6	–194	–32.1	–47	–23.1	–44	–19.4
20-24	–286	–55.2	–334	–60.5	–79	–45.0	–87	–47.7
25-29	–260	–57.3	–220	–52.6	–97	–62.6	–80	–52.6
30-34	–77	–25.9	–32	–10.1	–51	–44.7	–68	–44.9
35-39	–46	–15.4	–38	–11.3	–26	–31.2	–26	–24.1
40-44	–40	–11.2	–29	–8.2	–7	–8.4	–38	–40.8
45-49	–9	–2.6	–1	–0.2	–4	–6.2	–22	–22.1
50-54	–24	–7.7	–52	–15.3	–10	–11.9	–9	–9.7
55-59	–14	–4.7	1	0.3	–10	–16.8	–8	–10.5
60-64	0	0.0	4	1.5	–9	–18.3	–14	–20.7
65-69	28	12.7	0	0.0	3	4.6	6	10.4
Iberia								
15-19	–37	–2.6	7	0.5	–85	–11.3	–95	–11.7
20-24	–125	–10.1	15	1.3	–160	–27.6	–201	–29.1
25-29	207	20.4	183	16.9	–207	–35.4	–188	–28.5
30-34	275	27.8	104	8.9	–108	–24.1	–101	–19.8
35-39	95	8.4	55	4.8	–22	–5.7	–59	–12.6
40-44	83	7.9	52	4.8	–13	–3.1	8	1.8
45-49	19	1.8	24	2.4	–8	–2.1	–25	–6.2
50-54	–3	–0.4	32	4.0	1	0.4	–20	–6.0
55-59	2	0.3	0	0.0	–42	–15.2	–12	–4.7
60-64	8	1.7	20	3.8	2	1.2	13	6.3
65-69	13	3.4	–10	–1.9	0	0.0	15	7.4
Iberville								
15-19	–74	–11.5	–123	–17.1	–107	–13.6	–90	–11.5
20-24	–187	–31.8	–185	–29.0	–136	–23.2	–176	–29.7
25-29	–76	–14.8	–79	–13.8	–131	–25.8	–148	–29.2
30-34	–43	–7.9	–52	–9.6	–51	–13.7	–75	–19.2
35-39	–34	–6.4	–31	–5.8	–50	–14.2	–16	–4.2
40-44	–46	–9.4	–28	–5.6	–16	–4.8	–43	–11.3
45-49	–33	–7.1	–22	–4.6	–45	–13.5	–3	–0.8
50-54	–6	–1.4	–7	–2.0	12	4.3	–11	–3.3
55-59	9	2.5	2	0.6	–34	–11.5	–12	–3.7
60-64	–4	–1.5	–21	–6.9	34	17.2	30	12.2
65-69	5	2.2	–48	–17.6	–19	–7.8	–20	–6.4
Jackson								
15-19	–103	–18.5	–102	–18.0	–13	–4.8	–35	–13.0
20-24	–205	–40.4	–261	–41.4	–95	–40.9	–116	–44.9
25-29	–205	–46.2	–240	–48.5	–68	–39.3	–89	–36.8
30-34	–58	–16.5	–72	–19.9	–49	–35.3	–62	–32.6
35-39	–17	–5.4	–43	–11.5	–19	–15.8	–34	–18.9
40-44	–47	–12.0	–21	–4.8	–6	–4.6	3	2.3
45-49	–22	–5.5	–28	–6.4	23	18.2	0	0.0
50-54	17	4.7	21	6.0	9	8.2	9	7.5
55-59	6	2.0	3	1.1	2	2.2	18	18.5
60-64	–4	–2.0	8	3.5	7	9.5	12	17.6
65-69	12	7.1	10	4.2	21	35.2	42	18.2

APPENDIX II.—(Continued)

Parish and Age	Race and Sex							
	White				Nonwhite			
	Male		Female		Male		Female	
	No.	%	No.	%	No.	%	No.	%
Jefferson								
15-19	858	18.4	1117	24.1	279	32.2	360	39.0
20-24	698	21.9	1926	60.4	313	51.4	420	65.7
25-29	3382	129.0	4030	133.5	340	62.7	417	65.6
30-34	4609	135.5	3979	100.4	322	50.5	282	35.1
35-39	3429	79.1	2780	59.5	289	47.5	299	41.3
40-44	2128	56.5	1715	44.3	265	50.2	171	27.6
45-49	1456	41.4	1268	36.8	232	47.8	203	38.8
50-54	1006	33.7	996	34.4	195	42.8	160	33.4
55-59	810	36.0	862	39.3	152	35.7	81	19.7
60-64	445	25.9	532	32.4	104	38.1	77	27.0
65-69	235	21.3	373	28.4	54	21.8	96	43.4
Jefferson Davis								
15-19	–182	–15.9	–156	–14.8	–51	–14.7	–87	–24.5
20-24	–367	–38.8	–316	–30.8	–128	–42.5	–152	–45.1
25-29	–127	–15.1	–197	–21.5	–87	–33.2	–111	–34.1
30-34	–48	–6.1	–109	–12.6	–51	–23.4	–64	–26.5
35-39	–64	–8.4	–29	–3.7	–10	–7.3	–7	–3.7
40-44	–14	–2.0	2	0.3	–22	–16.9	–40	–21.7
45-49	12	1.7	–12	–1.8	–11	–8.0	5	3.4
50-54	–15	–2.3	–40	–6.5	5	4.8	8	6.2
55-59	–16	–3.3	9	1.7	10	10.7	–1	–1.4
60-64	–9	–2.3	–16	–3.8	13	20.7	–4	–5.1
65-69	1	0.3	17	4.9	16	24.6	–9	–10.1
Lafayette								
15-19	635	31.8	772	40.2	–73	–8.1	35	3.8
20-24	947	58.6	934	57.0	–33	–4.5	–84	–9.2
25-29	619	34.5	577	29.2	–75	–10.1	–107	–12.3
30-34	215	9.2	185	8.3	–94	–14.8	–118	–14.9
35-39	289	14.6	282	14.7	–13	–2.4	–79	–12.9
40-44	221	13.1	227	13.8	–31	–7.3	–25	–4.8
45-49	150	9.9	203	13.6	32	7.4	15	3.4
50-54	132	10.8	169	13.5	28	8.8	4	1.1
55-59	89	8.3	71	6.5	–16	–5.0	–14	–4.6
60-64	28	4.0	65	7.9	24	14.5	11	4.4
65-69	–5	–0.9	46	6.6	–5	–2.9	13	5.2
Lafourche								
15-19	–124	–5.9	–22	–1.0	–64	–16.6	–53	–15.0
20-24	–153	–8.6	–78	–4.2	–78	–28.1	–80	–27.0
25-29	66	4.1	–58	–3.3	–74	–28.5	–72	–27.6
30-34	202	12.7	132	8.5	–17	–8.7	–18	–8.1
35-39	104	7.0	109	7.4	4	2.0	–14	–7.4
40-44	103	7.2	53	4.0	–14	–9.6	–26	–13.5
45-49	67	5.6	12	1.0	8	5.9	–11	–7.4
50-54	63	6.2	45	4.8	9	7.9	3	3.1
55-59	29	3.7	0	0.0	2	2.3	–13	–11.7
60-64	50	9.2	–2	–0.3	4	5.6	–12	–12.1
65-69	–9	–1.8	15	2.5	–11	–11.6	2	1.9
LaSalle								
15-19	–118	–20.0	–159	–26.2	–2	–2.1	–7	–8.3
20-24	–294	–52.9	–248	–46.3	–24	–36.0	–22	–32.5
25-29	–209	–43.2	–189	–36.5	–18	–36.2	–20	–31.7
30-34	–36	–10.2	–30	–8.1	–16	–36.1	–2	–4.3
35-39	–21	–6.0	–32	–8.4	–8	–23.2	–10	–18.5
40-44	–50	–12.1	–59	–13.3	–5	–13.2	–5	–12.3
45-49	–9	–2.2	–27	–7.0	–3	–7.2	0	0.0
50-54	–28	–7.5	1	0.4	5	17.4	7	23.1
55-59	–17	–4.9	–11	–3.5	10	25.0	–1	–2.9
60-64	9	4.1	–5	–1.8	5	16.2	10	31.4
65-69	11	6.3	22	12.3	12	62.6	–3	–8.0

APPENDIX II.—(Continued)

Parish and Age	Race and Sex							
	White				Nonwhite			
	Male		Female		Male		Female	
	No.	%	No.	%	No.	%	No.	%
Lincoln								
15-19	645	111.4	356	56.5	119	22.1	460	79.1
20-24	668	121.0	157	25.9	247	59.1	443	85.7
25-29	–328	–40.0	–471	–53.4	–230	–44.7	–308	–47.8
30-34	–716	–65.1	–307	–42.5	–323	–57.3	–374	–53.4
35-39	–204	–34.1	–94	–18.1	–90	–28.5	–79	–20.2
40-44	–73	–14.7	–56	–11.8	–37	–14.2	–12	–3.9
45-49	–35	–7.7	–31	–6.1	–25	–9.6	–43	–15.3
50-54	–8	–1.7	6	1.2	–5	–2.4	14	5.8
55-59	–17	–4.6	–5	–1.1	4	2.3	6	2.7
60-64	15	5.6	11	3.3	15	11.4	–14	–8.5
65-69	18	7.4	4	1.4	12	9.7	35	29.3
Livingston								
15-19	–32	–3.1	–42	–4.0	–18	–10.6	9	5.3
20-24	–231	–26.5	–109	–12.7	–23	–16.8	13	9.4
25-29	–71	–9.4	–17	–2.4	–14	–10.2	–33	–21.2
30-34	95	15.6	119	17.9	–14	–9.9	–3	–2.5
35-39	147	24.2	129	19.8	–11	9.9	1	0.8
40-44	101	17.4	49	8.8	–13	–15.0	9	12.2
45-49	71	12.6	81	15.6	7	8.3	–13	–14.0
50-54	56	10.8	49	10.8	–7	–9.0	8	10.4
55-59	64	16.2	44	11.0	–13	–17.6	–12	–19.0
60-64	19	5.9	47	15.7	2	3.9	12	38.5
65-69	69	30.3	28	9.9	–5	–13.5	10	30.9
Madison								
15-19	–102	–32.6	–149	–39.1	–181	–28.3	–200	–29.7
20-24	–154	–54.1	–164	–53.8	–330	–64.5	–313	–56.9
25-29	–82	–38.0	–41	–18.1	–237	–54.9	–248	–52.5
30-34	–19	–9.1	–4	–1.9	–188	–52.5	–201	–44.4
35-39	–17	–8.9	–39	–18.1	–147	–45.6	–86	–24.8
40-44	–21	–10.3	–46	–18.5	–72	–28.4	–70	–22.3
45-49	–33	–14.6	–16	–7.5	–42	–16.1	–74	–20.5
50-54	–31	–14.7	0	0.0	–51	–19.4	–60	–18.7
55-59	–18	–10.2	–30	–18.2	–85	–26.1	–51	–16.8
60-64	–20	–16.2	–2	–2.2	–21	–8.8	–15	–5.8
65-69	–6	–5.6	–12	–11.7	41	2.1	42	19.6
Morehouse								
15-19	–191	–20.3	–182	–19.8	–203	–23.6	–264	–28.7
20-24	–305	–41.7	–292	–37.0	–389	–54.3	–310	–40.5
25-29	–175	–26.8	–82	–11.8	–358	–56.2	–358	–45.9
30-34	–53	–7.8	–88	–11.9	–240	–45.6	–239	–38.1
35-39	–102	–14.4	–73	–10.2	–108	–27.1	–113	–23.7
40-44	–92	–13.8	–68	–10.6	–126	–31.8	–71	–15.8
45-49	–75	–12.2	–21	–3.6	–36	–10.4	–52	–11.5
50-54	–29	–5.8	–17	–3.5	–35	–10.9	–58	–13.5
55-59	–7	–1.9	28	7.8	–47	–13.0	–37	–10.3
60-64	28	11.2	31	10.0	–20	–7.4	–6	–2.1
65-69	29	13.3	38	16.5	51	22.5	76	28.9
Natchitoches								
15-19	131	11.9	192	17.2	–203	20.0	–309	–28.7
20-24	–9	–0.9	–237	–24.4	–519	–57.3	–550	–57.0
25-29	–477	–49.7	–758	–61.4	–506	–65.4	–463	–54.2
30-34	–400	–46.8	–326	–38.2	–270	–49.9	–256	–41.0
35-39	–192	–27.5	–148	–21.3	–123	–29.0	–112	–21.2
40-44	–111	–16.7	–119	–16.7	–107	–27.2	–101	–21.7
45-49	–132	–19.5	–91	–13.5	–62	–14.9	–23	–5.3
50-54	–40	–6.8	–63	–10.2	–2	–0.6	–28	–6.6
55-59	–43	–8.4	–34	–6.9	–47	–14.4	–75	–19.8
60-64	4	1.0	–17	–3.8	8	3.3	21	7.3
65-69	5	1.5	15	4.0	12	4.9	11	3.9

APPENDIX II.—(Continued)

Parish and Age	Race and Sex							
	White				Nonwhite			
	Male		Female		Male		Female	
	No.	%	No.	%	No.	%	No.	%
Orleans								
15-19	−1181	−8.3	89	0.6	107	1.3	655	7.7
20-24	1324	13.2	2255	20.6	516	8.8	1281	18.5
25-29	317	2.8	−1312	−10.5	728	13.0	621	8.6
30-34	−3966	−24.2	−4935	−25.8	174	2.7	−107	−1.3
35-39	−4468	−24.5	−3699	−19.9	9	0.1	−152	−1.8
40-44	−2482	−16.4	−1815	−11.6	55	0.9	−342	−4.7
45-49	−1638	−11.4	−1599	−10.3	−72	−1.2	−472	−6.5
50-54	−1205	−9.0	−1302	−8.6	126	2.4	−150	−2.3
55-59	−930	−7.8	−910	−6.8	−41	−0.8	−323	−5.6
60-64	−811	−8.3	−1057	−9.3	−152	−4.4	−108	−2.8
65-69	−856	−11.5	−452	−4.8	−104	−3.5	−174	−4.9
Ouachita								
15-19	365	15.3	470	20.3	−2	−0.1	74	6.2
20-24	306	16.2	510	25.0	−132	−14.8	23	2.2
25-29	444	25.8	478	24.3	−163	−20.6	27	2.8
30-34	520	28.4	152	6.3	−152	−17.6	−78	−6.8
35-39	268	13.0	50	2.2	−54	−7.1	−91	−8.7
40-44	167	8.7	201	10.0	−61	−8.2	−23	−2.4
45-49	93	5.1	104	5.4	41	5.9	46	5.3
50-54	56	3.4	111	6.5	87	13.8	62	8.2
55-59	68	4.8	51	3.4	27	4.5	28	3.8
60-64	36	3.4	108	9.7	28	6.2	84	18.0
65-69	80	10.3	110	12.4	107	27.4	95	21.0
Plaquemines								
15-19	74	16.8	119	28.3	−57	−14.6	−22	−6.9
20-24	242	71.8	264	73.4	−41	−15.6	−62	−20.1
25-29	405	126.0	312	93.8	−79	−29.0	−74	−25.9
30-34	312	75.4	234	59.5	−39	−18.1	−36	−16.3
35-39	231	55.7	148	40.3	−34	−18.6	−12	−7.0
40-44	118	33.5	76	23.1	−24	−14.0	−17	−10.7
45-49	74	20.8	71	22.0	−3	−1.7	−19	−13.4
50-54	43	13.0	33	11.7	0	0.0	−1	−1.0
55-59	16	6.1	16	8.8	−11	−10.4	−8	−8.3
60-64	−4	−2.3	11	7.5	0	0.0	−13	−23.5
65-69	10	7.9	−5	−4.8	7	11.8	−13	−15.3
Pointe Coupee								
15-19	−138	−25.1	−137	−25.7	−186	−22.8	−144	−12.4
20-24	−165	−38.0	−220	−45.7	−225	−39.1	−321	−49.1
25-29	−189	−42.0	−182	−39.7	−262	−53.6	−262	−48.4
30-34	−79	−20.1	−47	−12.6	−114	−34.1	−117	−31.8
35-39	−49	−13.2	−55	−15.1	−17	−7.1	−80	−22.6
40-44	−24	−7.2	−37	−10.1	−64	−21.2	−57	−18.4
45-49	−28	−8.0	1	0.3	−41	−15.0	−9	−3.1
50-54	4	1.2	2	0.8	6	2.4	−11	−4.5
55-59	4	1.4	−12	−4.3	−34	−14.4	−26	−11.1
60-64	25	12.4	−12	−5.8	5	3.3	−20	−10.7
65-69	3	1.7	9	4.2	12	8.0	−2	−1.1
Rapides								
15-19	−95	−3.1	190	6.4	−157	−10.3	−151	−10.2
20-24	397	16.3	73	2.8	−231	−19.5	−322	−22.6
25-29	491	24.0	48	1.9	−176	−17.2	−334	−25.6
30-34	397	19.2	77	3.1	−129	−13.8	−157	−12.5
35-39	187	8.5	115	4.4	−167	−17.2	−222	−18.3
40-44	95	4.0	66	2.8	−94	−10.4	−55	−5.1
45-49	−45	−2.0	22	1.0	−13	−1.5	−25	−2.5
50-54	8	0.4	6	0.3	−22	−2.8	−8	−0.8
55-59	−39	−2.4	31	1.8	17	2.4	20	2.5
60-64	−33	−2.7	88	6.5	−2	−0.3	−44	−6.9
65-69	−43	−4.1	31	2.6	23	4.4	74	13.2

APPENDIX II.—(Continued)

Parish and Age	Race and Sex							
	White				Nonwhite			
	Male		Female		Male		Female	
	No.	%	No.	%	No.	%	No.	%
Red River								
15-19	–131	–37.8	–121	–40.3	–112	–30.8	–163	–38.9
20-24	–201	–67.1	–214	–66.0	–212	–66.9	–218	–61.9
25-29	–145	–56.7	–130	–52.7	–205	–74.0	–202	–66.0
30-34	–33	–22.7	–37	–21.9	–116	–64.5	–125	–55.3
35-39	–33	–20.5	–31	–17.5	–38	–30.0	–53	–29.0
40-44	–35	–17.6	–38	–17.5	–54	–39.8	–45	–30.0
45-49	–26	–13.7	–9	–4.2	–17	–14.3	–43	–27.5
50-54	–5	–2.8	–17	–8.0	–37	–27.4	–27	–18.0
55-59	–16	–9.9	–21	–12.4	–30	–22.8	–24	–18.6
60-64	12	9.0	21	14.6	4	4.6	–1	–0.6
65-69	–1	–0.8	–10	–7.0	–2	–2.6	–11	–10.7
Richland								
15-19	–298	–32.8	–315	–34.6	–172	–25.0	–189	–26.3
20-24	–521	–63.2	–550	–63.6	–273	–55.1	–348	–57.5
25-29	–434	–60.5	–403	–54.3	–356	–68.1	–288	–55.5
30-34	–159	–31.4	–178	–29.7	–138	–43.0	–139	–36.1
35-39	–132	–24.5	–150	–25.9	–96	–38.7	–91	–28.1
40-44	–105	–20.3	–105	–19.2	–39	–17.6	–50	–16.4
45-49	–103	–19.2	–70	–14.0	–37	–13.6	–57	–17.9
50-54	–64	–14.2	–84	–18.5	–43	–17.9	–65	–22.6
55-59	–14	–3.7	–22	–6.0	–64	–26.2	–39	–15.4
60-64	–23	–8.1	–36	–11.9	27	17.7	10	5.5
65-69	–25	–11.1	–23	–9.3	–4	–2.4	26	14.7
Sabine								
15-19	–239	–29.3	–333	–33.1	–81	–30.4	–42	–17.4
20-24	–591	–65.4	–592	–67.2	–74	–41.0	–108	–47.6
25-29	–456	–63.6	–429	–61.5	–100	–55.2	–93	–43.8
30-34	–133	–31.4	–147	–29.3	–52	–33.2	–63	–39.3
35-39	–147	–30.4	–164	–28.5	–43	–38.6	–29	–19.6
40-44	–72	–14.5	–96	–17.4	–15	–13.8	–20	–18.2
45-49	–94	–17.7	–66	–12.7	–6	–7.6	–11	–9.2
50-54	–55	–11.0	–47	–9.7	0	0.0	–12	–9.3
55-59	–23	–5.5	–39	–8.7	17	19.5	–4	–3.5
60-64	17	5.4	–24	–6.9	1	1.6	–1	–0.9
65-69	11	3.6	–4	–1.2	2	2.3	–5	–6.2
St. Bernard								
15-19	421	85.8	462	93.9	–9	–10.6	4	3.6
20-24	220	57.7	418	104.6	–3	–3.2	18	29.0
25-29	632	202.9	865	240.5	–4	–6.2	7	9.1
30-34	1055	257.8	1052	236.2	14	23.1	9	10.5
35-39	997	202.5	900	182.2	12	22.1	–1	–1.3
40-44	642	183.3	452	122.9	10	23.7	–2	–2.7
45-49	418	118.2	341	100.0	14	41.1	13	28.4
50-54	203	69.4	225	82.1	10	32.8	–2	–4.3
55-59	160	60.8	152	64.1	–8	–19.2	11	37.2
60-64	81	44.8	135	80.3	8	28.5	1	3.0
65-69	62	44.4	78	60.5	3	15.4	1	3.3
St. Charles								
15-19	7	1.5	50	11.1	1	0.3	–16	–5.6
20-24	–30	–7.8	93	23.0	–15	–8.3	–28	–12.2
25-29	202	48.5	206	45.1	–38	–20.3	–11	–6.6
30-34	295	77.8	218	58.6	–9	–6.2	–15	–9.2
35-39	176	46.0	135	36.1	–10	–7.9	20	14.2
40-44	133	46.1	101	33.5	–4	–3.8	20	17.5
45-49	39	12.7	50	17.0	23	23.5	7	6.5
50-54	44	15.8	18	5.9	13	14.9	17	20.2
55-59	31	11.9	2	0.9	0	0.0	–8	–8.8
60-64	22	11.4	–3	–1.7	14	23.6	20	25.9
65-69	2	1.5	18	12.3	5	8.0	10	11.9

APPENDIX II.—(Continued)

Parish and Age	Race and Sex							
	White				Nonwhite			
	Male		Female		Male		Female	
	No.	%	No.	%	No.	%	No.	%
St. Helena								
15-19	–61	–29.6	–61	–27.5	–58	–16.7	–62	–18.8
20-24	–105	–54.9	–122	–57.0	–115	–43.4	–165	–52.9
25-29	–103	–50.5	–65	–36.8	–159	–67.3	–163	–57.2
30-34	–25	–19.0	–14	–11.7	–63	–41.0	–76	–42.7
35-39	–25	–16.8	–18	–13.2	–33	–29.2	–33	–27.7
40-44	–13	–9.4	–10	–6.7	–23	–21.8	–7	–6.0
45-49	–1	–0.6	–7	–5.1	–2	–1.9	–14	–10.9
50-54	–7	–4.9	–16	–12.3	–9	–7.0	2	1.6
55-59	–9	–7.6	–7	–6.8	12	15.0	16	20.7
60-64	–4	–4.5	–4	–4.5	0	0.0	3	5.1
65-69	–10	–13.3	–2	–1.7	4	9.2	11	18.5
St. James								
15-19	–45	–10.9	–38	–9.5	–26	–5.3	–66	–12.5
20-24	–134	–34.9	–70	–19.0	–104	–26.3	–133	–32.8
25-29	–66	–19.2	–37	–11.6	–101	–33.9	–105	–32.2
30-34	–3	–1.1	32	12.1	–45	–20.6	–7	–3.1
35-39	–6	–2.3	8	3.4	–48	–22.7	6	2.7
40-44	10	4.2	4	1.8	11	6.1	–10	–4.9
45-49	–2	–0.8	0	0.0	–2	–1.1	–8	–4.1
50-54	23	10.7	0	0.0	16	11.0	18	13.1
55-59	1	0.7	–13	–6.3	–31	–19.3	–1	–0.5
60-64	–8	–5.4	2	1.0	10	11.0	–4	–3.0
65-69	10	7.6	7	5.1	–26	–17.6	18	13.2
St. John The Baptist								
15-19	–64	–16.8	–58	–15.3	–14	–3.0	–8	–1.7
20-24	–86	–24.5	–56	–16.2	–72	–19.8	–94	–22.4
25-29	–85	–24.5	–31	–9.7	–60	–20.4	–55	–17.5
30-34	4	1.2	–26	9.4	–34	–12.4	–8	–2.8
35-39	10	3.8	–6	–2.3	0	0.0	–11	–4.3
40-44	–3	–1.3	2	0.8	25	13.1	2	0.8
45-49	20	8.3	–8	–3.2	4	2.0	–2	–1.0
50-54	19	8.2	8	3.5	12	6.6	18	11.3
55-59	14	7.9	–2	–1.0	–4	–2.4	23	15.0
60-64	17	11.1	–3	–1.8	6	5.2	–1	–0.7
65-69	0	0.0	6	5.0	–3	–2.8	19	17.6
St. Landry								
15-19	–465	–19.7	–532	–22.5	–469	–19.3	–509	–19.5
20-24	–899	–42.0	–871	–39.8	–929	–45.8	–1145	–49.3
25-29	–581	–30.1	–617	–30.5	–994	–56.6	–1096	–56.3
30-34	–311	–17.0	–354	–18.2	–480	–41.0	–561	–39.3
35-39	–283	–16.8	–253	–14.9	–211	–23.0	–186	–17.3
40-44	–206	–12.7	–147	–9.2	–89	–10.8	–88	–9.3
45-49	–79	–5.2	–92	–6.2	–106	–11.9	–36	–4.0
50-54	–115	–8.5	–90	–7.3	–22	–3.4	–72	–10.2
55-59	–3	–0.3	–12	–1.1	–61	–10.5	–37	–6.5
60-64	–15	–1.9	–19	–2.2	41	10.3	17	3.8
65-69	–42	–6.9	–11	–1.6	–17	–4.6	–12	–2.8
St. Martin								
15-19	–131	–13.5	–122	–14.2	–102	N.A.*	–104	–14.9
20-24	–318	–35.5	–299	–35.0	–118	N.A.	–206	–33.5
25-29	–252	–33.1	–257	–32.5	–215	N.A.	–227	–42.9
30-34	–130	–20.2	–83	–12.7	–116	N.A.	–129	–32.4
35-39	–85	–14.4	–49	–8.2	–68	N.A.	–40	–13.1
40-44	–17	–3.2	–50	–8.8	–20	N.A.	–17	–6.1
45-49	–66	–11.8	–16	–3.1	–36	–13.6	–36	–13.5
50-54	–18	–3.7	–6	–1.2	0	0.0	17	10.7
55-59	–1	–0.2	–19	–4.5	2	1.2	–11	–6.6
60-64	–30	–9.9	5	1.5	–3	–3.2	10	10.2
65-69	–28	–10.6	15	5.5	12	10.8	–6	–5.0

Parish and Age	Race and Sex							
	White				Nonwhite			
	Male		Female		Male		Female	
	No.	%	No.	%	No.	%	No.	%
St. Mary								
15-19	56	4.4	190	16.2	–153	–18.0	–137	–16.8
20-24	32	3.2	231	23.5	–171	–25.2	–238	–33.1
25-29	412	51.3	339	36.6	–202	–37.9	–174	–30.2
30-34	431	48.7	264	27.6	–115	–25.3	–106	–21.8
35-39	226	24.7	223	25.6	–45	–11.5	–58	–14.0
40-44	246	31.6	121	14.6	–66	–18.7	–11	–2.5
45-49	131	16.0	91	12.3	0	0.0	–30	–7.4
50-54	51	7.5	30	4.6	–10	–3.4	–12	–3.9
55-59	16	2.7	7	1.4	–59	–17.7	–25	–8.3
60-64	25	6.7	–16	–3.9	–7	–3.5	–31	–13.4
65-69	–7	–2.4	7	2.0	4	1.7	9	3.7
St. Tammany								
15-19	120	11.8	99	9.4	–29	–6.2	–41	–8.7
20-24	–194	–23.5	–83	–9.4	–67	–17.7	–23	–5.6
25-29	10	1.3	99	13.1	–61	–19.1	–56	–14.9
30-34	277	45.2	257	40.7	30	12.3	–14	–4.8
35-39	267	43.3	299	46.4	19	8.0	38	14.7
40-44	218	37.3	257	41.2	–1	–0.6	21	8.1
45-49	183	32.0	125	19.6	26	11.7	34	13.3
50-54	167	30.4	195	32.8	26	13.8	21	11.5
55-59	141	28.7	93	16.7	15	8.6	–21	–11.8
60-64	154	35.5	113	22.9	15	14.5	16	13.6
65-69	75	19.8	100	24.6	17	13.8	15	11.0
Tangipahoa								
15-19	–21	–1.1	8	0.4	–80	–8.3	–124	–12.1
20-24	–378	–22.6	–505	–29.5	–165	–23.5	–247	–30.3
25-29	–611	–38.2	–638	–37.1	–234	–36.1	–285	–34.8
30-34	–384	–25.5	–235	–17.1	–136	–25.0	–102	–15.3
35-39	–198	–15.0	–156	–11.6	–62	–11.7	–97	–15.2
40-44	–27	–2.3	–52	–4.0	16	3.7	–4	–0.9
45-49	–57	–4.8	–35	–2.7	22	4.9	–35	–7.0
50-54	–32	–2.7	8	0.6	–43	–9.4	34	7.7
55-59	–33	–3.3	17	1.8	–15	–4.0	–2	–0.6
60-64	2	0.3	–32	–4.4	41	14.6	23	8.0
65-69	13	2.3	43	7.0	20	7.5	76	27.9
Tensas								
15-19	–68	–23.8	–98	–33.6	–159	–31.7	–160	–31.9
20-24	–140	–63.1	–153	–63.7	–269	–69.0	–232	–56.8
25-29	–86	–48.8	–95	–49.1	–251	–73.8	–221	–63.1
30-34	–34	–25.0	–43	–25.8	–127	–60.7	–118	–42.3
35-39	–37	–24.2	–29	–16.2	–66	–39.4	–65	–26.8
40-44	–20	–12.6	–39	–21.3	–50	–28.1	–54	–24.8
45-49	–33	–19.5	–28	–18.0	–37	–19.8	–37	–14.7
50-54	–1	–0.7	–8	–6.2	–34	–18.0	–40	–15.6
55-59	–14	–11.6	–13	–12.2	–42	–21.1	–30	–13.7
60-64	–5	–5.8	–26	–27.9	1	1.0	–9	–5.0
65-69	–19	–25.3	–21	–27.0	–15	–9.2	–22	–11.5
Terrebonne								
15-19	–44	–2.3	43	2.2	–79	–11.9	–118	–17.2
20-24	36	2.4	166	10.2	–115	–21.9	–192	–31.2
25-29	496	37.2	336	24.0	–109	–25.8	–155	–31.5
30-34	395	27.2	292	20.8	–50	–14.1	–73	–17.8
35-39	186	13.8	157	11.7	–76	–21.6	–67	–18.3
40-44	105	8.8	89	7.4	13	4.9	–7	–2.6
45-49	112	9.9	105	10.2	–33	–10.7	–26	–9.0
50-54	32	3.5	28	3.4	5	2.3	–7	–3.3
55-59	35	4.9	46	6.6	–26	–14.3	–8	–4.1
60-64	5	1.0	22	4.2	–10	–7.4	18	14.1
65-69	–23	–5.7	–12	–2.5	–15	–9.7	22	15.1

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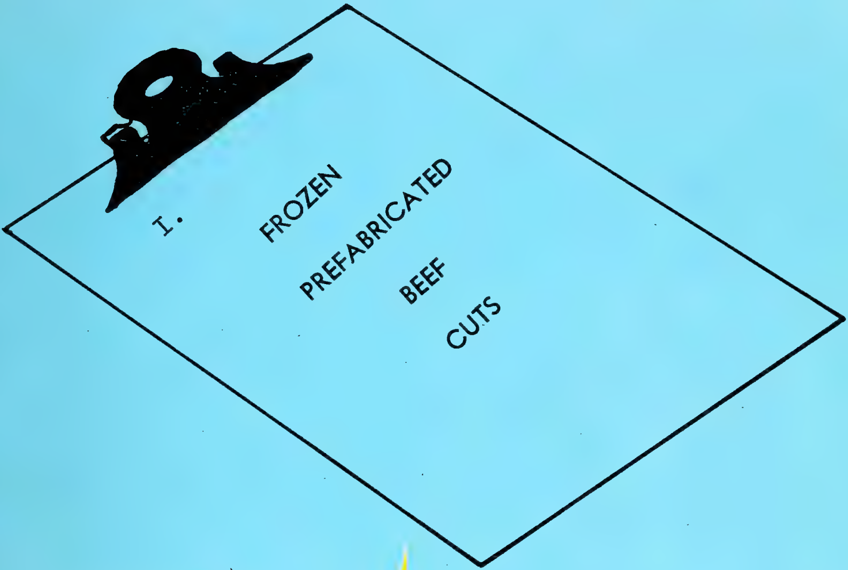
CONSUMER ACCEPTANCE STUDIES



I. FROZEN PREFABRICATED BEEF CUTS

SCHOOL OF HOME
ECONOMICS
and
DEPARTMENTS
of
ANIMAL SCIENCE and
GRICULTURAL ECONOMICS AND
AGRIBUSINESS

HELEN M. LAW
MARIANNE S. BEESON
ALMA BETH CLARK
AUTTIS M. MULLINS
GENE E. MURRA

Louisiana State University and
Agricultural and Mechanical College
Agricultural Experiment Station
Doyle Chambers, Director

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Southern Regional Research Project SM-19

This report is Part I of a contributing project to Southern Regional Research Project SM-19, "Quality of Beef and Factors Motivating Beef Purchases."

Consumer Acceptance Studies
I. Frozen Prefabricated Beef Cuts

HELEN M. LAW,[1] MARIANNE S. BEESON,[1] ALMA BETH CLARK,[1]
AUTTIS M. MULLINS,[2] AND GENE E. MURRA[3]

Summary of Results

1. Prefabricated beef was highly acceptable to a majority of 38 high income families in Baton Rouge.
2. Choice grade beef was rated significantly higher than Standard grade for those cuts cooked by dry heat, but there were no significant differences between grades for those cooked by moist heat.
3. A large majority of respondents stated that they would be willing to buy prefabricated beef if it were available in retail stores.
4. Choice broiling steaks gained the widest acceptance of all the prefabricated cuts.

Introduction

Prefabrication of beef, which involves the processing of carcasses into boneless, portion-size cuts according to tenderness of the muscles, offers advantages to both the meat processor and the consumer. Since the degree of tenderness determines how the meat is cooked, the similar tenderness qualities of muscles within each prefabricated cut result in better utilization of the muscle portion of beef. Trimming exterior fat and removing bone at an early processing stage would permit more effective utilization of these by-products. Otherwise such by-products are transported across the nation, wrapped into retail meat packages, and finally discarded by the housewife. In additon, prefabrication appears to minimize grade effect, as shown by recent studies (*4*) at Louisiana State University using a trained taste panel and laboratory tests.

The removal of exterior fat and bone by the meat processor or retailer offers many advantages to the consumer. Ease of storing, cooking, and carving are only a few. Portion control is also implied; for this reason, prefabricated beef has been used extensively by the Armed Forces, hospitals, and restaurants. With waste fat and bone removed, the consumer pays only for edible meat. Therefore, while the actual price per pound is higher for prefabricated beef than for conventional cuts, the cost of the edible portion is essentially the same. However, will consumers accept and buy this type of beef which outwardly appears to be more expensive than they are accustomed to buying?

This study was designed to answer this question by determining the reactions of selected consumers to prefabricated beef cuts from

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[1] School of Home Economics.

[2] Department of Animal Science.

[3] Department of Agricultural Economics and Agribusiness.

Prefabrication is illustrated in these two photos. Top: Regular arm pot roast prefabricated into a rolled pot roast and two swiss steaks. Bottom: Conventional porterhouse steak prefabricated into a filet, a loin strip steak, and chopped beef.

both U.S. Choice and Standard grades, grouped according to cooking methods. Results of this study should serve as one indication of the potential success of prefabricated beef on the retail market.

Procedure

Selection of the Family Panel

The panel was limited to white families in Baton Rouge, Louisiana, who had a yearly income of $7,000 or over and who had available freezer storage space. This upper income level was chosen because it was felt that this would be the income level customarily using this type of beef. Considerable difficulty was encountered in finding enough families to participate, since the families were required to purchase the meat* to help defray the cost.

A commercial directory (*3*), which indicated the number of residences and the income level for each street in Baton Rouge, was used in selecting the sample. The streets in the upper income segments were combined into four areas of the city, each containing approximately one-quarter of the total number of residences. The sample streets for each area were then selected by a random number table. Ten families were selected from each area. Over 200 families were interviewed to select the 38 families used in the study.

An initial interview was used for selection of the families and to obtain their reactions to, and habits of using, frozen meat. After the families had used the prefabricated beef they were interviewed again to get their overall opinions of the meat. Interviews were conducted by members of the Home Economics Marketing Research staff in the spring of 1963.

Fabrication of the Meat

Carcasses from animals of known history, grading U.S. Choice and Standard and weighing from 500 to 700 pounds, were fabricated into boneless round, sirloin, short loin, rib, chuck, and brisket. These cuts were further fabricated into portion-size steaks and family-size roasts, retaining the identity of the cut and location within the cut. All cuts were packaged for freezer storage. Each package contained a rating sheet which families were asked to complete after consumption of the particular cut.

Cooking Methods

The packages were labeled according to four cooking methods: broiling steak, swiss steak, oven roast, and pot roast. Each family re-

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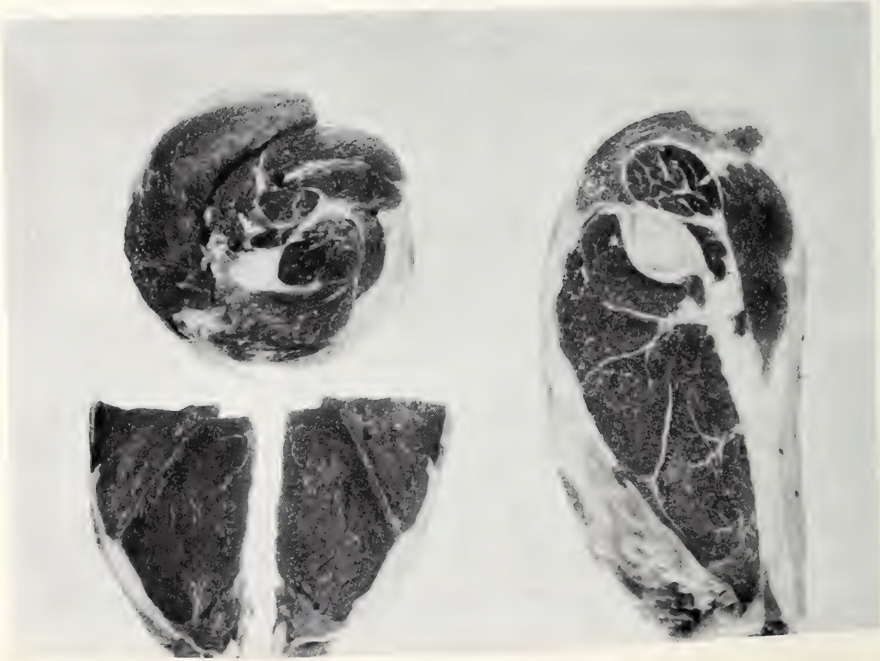
The legend on Page 4, Bulletin No. 596, *Consumer Acceptance Studies. I. Frozen Prefabricated Beef Cuts,* should read as follows:

Prefabrication is illustrated in these two photos. Top: A loin strip, filet, and chopped beef fabricated from the conventional porterhouse steak. Bottom: Rolled pot roast and two swiss steaks fabricated from the conventional arm pot roast.



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Carcasses from animals of known history, grading U.S. Choice and Standard and weighing from 500 to 700 pounds, were fabricated into boneless round, sirloin, short loin, rib, chuck, and brisket. These cuts were further fabricated into portion-size steaks and family-size roasts, retaining the identity of the cut and location within the cut. All cuts were packaged for freezer storage. Each package contained a rating sheet which families were asked to complete after consumption of the particular cut.

Cooking Methods

The packages were labeled according to four cooking methods: broiling steak, swiss steak, oven roast, and pot roast. Each family received a total of 24 packages, 3 from the Choice grade and 3 from the Standard grade for each of the four cooking methods. The homemakers agreed to prepare the beef according to standard recipes and to evaluate each package by rating the factors—tenderness, flavor, juiciness, and general liking—according to a 5-point hedonic scale. The rating scale included "liked very much," "liked slightly," "neither liked nor disliked," "disliked slightly," and "disliked very much."

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*90 pounds of meat per family for $75.

Characteristics of the Family Panel (Table 1)

Income

The panel was composed of 38 white families in Baton Rouge, Louisiana, who had an annual income of $7,000 or more. Ten families had an income between $7,000 and $9,000, 15 families were between $9,000 and $11,000, and 13 families had an income of $11,000 or more.

TABLE 1.—Characteristics of the Family Panel

Classification	Number	Percent*
Family Income		
$7,000 to $9,000	10	26.3
$9,000 to $11,000	15	39.5
$11,000 or more	13	34.2
Occupation of Husband		
Professional	17	44.7
Managerial	12	31.6
Sales	3	7.9
Craftsmen	4	10.5
Operatives	2	5.3
Education of Husband		
High School Graduate	4	10.5
Some College or Trade School	9	23.7
College Graduate	11	29.0
Postgraduate Work	14	36.8
Education of Homemaker		
High School Graduate	9	23.7
Some College or Trade School	19	50.0
College Graduate	6	15.8
Postgraduate Work	4	10.5
Age of Husband		
20 to 30 years	1	2.6
30 to 50 years	29	76.3
50 to 70 years	8	21.1
Age of Homemaker		
20 to 30 years	4	10.5
30 to 50 years	31	81.6
50 to 70 years	3	7.9
Number of Persons in Household		
Two	1	2.6
Three	5	13.2
Four	10	26.3
Five	12	31.6
Six	9	23.7
Seven	1	2.6

*Percentages for each total 100.

Occupation of the Husbands

The professional and managerial group, consisting of professors, doctors, lawyers, graduate engineers, and managers and owners of their own businesses, comprised three-quarters of the sample (*1*). Craftsmen, foremen, operatives, and other skilled classifications accounted for six of the husbands, and sales work for three of the husbands.

All of the wives were full-time homemakers.

Education

All of the homemakers and their husbands were high school graduates. Twenty-five of the husbands were also college graduates, with 14 of these having done postgraduate work. Nine of the husbands had some college or trade school education beyond high school.

Ten of the homemakers were also college graduates, with 4 of these having completed some postgraduate work. Nineteen homemakers had received some college or trade school education beyond high school.

Family Size and Ages

Families ranged in size from 2 to 7 persons, with an average of 4.6 persons. This is slightly larger than the Baton Rouge average, which in 1960 was 3.43 persons (*2*). A majority of the husbands and wives were between the ages of 30 and 50 years.

Comparison to Total Baton Rouge Population

The median family income (*2*) in 1960 for Baton Rouge was $5,789. The panel in this study was drawn from the upper income level as described. As one might expect with these high incomes, the great majority (76 percent) of the husbands' occupations were classified in the professional and managerial group. Only 29 percent of the total male working force in Baton Rouge was in this group. The median number of years of school completed by adults in Baton was 11.9 in 1960. The considerably higher educational level of adults in this sample is to be expected in view of the high income level and occupational classifications.

Habits of Buying and Using Fresh and Frozen Beef

Most of the respondents said they liked to use frozen beef, although most homemakers used beef that was bought fresh and frozen at home. (One of the requirements for participation in the study was the availability of ample freezer space.) Very few used commercially frozen meat of any kind. Convenience and economy were the main reasons given for using frozen beef.

Loin steaks were served by most of the respondents once or twice a week, while oven roasts, pot roasts, and round steaks were served by most families once a week or twice a month. Seven respondents said they never served pot roasts and two reported they never served round steaks (Table 2).

When asked what grade of beef they usually bought, almost half of the respondents mentioned Choice, and 8 percent mentioned other USDA grades, such as Prime and Good. However, it was not known whether all the homemakers who said they bought Choice beef were actually getting Choice grade. Other designations given were "top quality," "Grade A," "A&P Good," "heavy beef," and "Swift's Premium." Two homemakers did not know what grade of beef they purchased (Table 3). Color, marbling, and a small or reasonable amount of fat were given most frequently as characteristics looked for in top quality beef (Table 4).

Most of the respondents (63 percent) said they usually bought their meat at large national chain stores. Local chain stores were named by 16 percent. Others listed were local meat markets, local groceries, local meat packers, and food freezer plans. Quality, convenience, economy, and service were some of the more common reasons for buying meat at a particular store.

TABLE 2.—Frequency Respondents Serve Specific Beef Cuts

Frequency	Loin steaks		Round steaks		Pot roasts		Oven roasts	
	No.	Percent	No.	Percent	No.	Percent	No.	Percent
More than twice per week	7	18.4	2	5.3	1	2.6	1	2.6
Twice per week	9	23.7	3	7.9	0	0.0	0	0.0
Once per week	11	28.9	15	39.4	13	34.2	19	50.0
Twice per month	5	13.2	9	23.7	11	29.0	11	29.0
Less than twice per month	6	15.8	7	18.4	6	15.8	7	18.4
Never	0	0.0	2	5.3	7	18.4	0	0.0

TABLE 3.—Grade of Beef Usually Bought, As Reported by Respondents

Grade	Number	Percent
Choice	14	36.9
Top quality	5	13.2
Grade A	3	7.9
Choice and Good (depending on cut)	3	7.9
A & P Good grade	2	5.3
Don't know	2	5.3
Heavy beef	2	5.3
Prime	1	2.6
Good	1	2.6
Swift's Premium	1	2.6
What looks best	1	2.6
Grade B	1	2.6
Premium and Choice	1	2.6
Grade A and Prime	1	2.6

TABLE 4.—Characteristics Looked For in Top Quality Beef

Characteristic		Number*	Percent**
Color		31	81.6
Dark or deep	(10) 26.3%		
Medium	(9) 23.7%		
Color in general	(7) 18.4%		
Bright	(5) 13.2%		
Marbling		25	65.8
Small or reasonable amount of fat		22	57.9
Heavy beef		7	18.4
Fresh appearance		7	18.4
Well trimmed		7	18.4
Thickness appropriate to cut; well cut; size suitable for family		7	18.4
Small amount of bone		7	18.4
Aged appearance		5	13.2
Small amount of gristle, waste		5	13.2
White fat; color of fat in general		3	7.9
Fine grain or texture of lean		3	7.9
Cut across grain		3	7.9
Flavor and tenderness (through previous experience)		2	5.3
Price		2	5.3
Good fat covering		1	2.6
Texture of fat		1	2.6
General appearance		1	2.6
Prefer boneless		1	2.6
Fresh odor		1	2.6
Government grade		1	2.6

*Multiple answers.
**Percent of 38 respondents.

Sources of Help in Learning to Select Beef

As a supplement to a previous study (5), respondents were asked to check all those sources which were of help to them in learning to select beef. Eighty-four percent checked individual sources, such as butcher, mother or mother-in-law, relative, friends, husband; 61 percent checked trial and error, and 58 percent indicated professional sources, such as home economics courses, cooking schools, cookbooks, home demonstration clubs, leaflets, and USDA publications. News media and demonstrations were checked by 37 percent (Table 5).

The panel in this study listed fewer individual sources and more professional sources than those in the previous study. This was probably because income and education were considerably higher than in the previous study.

Consumer Evaluation of Prefabricated Cuts

Influence of Grade

Acceptability ratings for both Choice and Standard grades of all cooking methods were high. Results showed that a majority of re-

TABLE 5.—Sources of Help in Learning to Select Beef, As Given by Respondents

Source	Number*	Percent**
Individuals: butcher, mother, mother-in-law, relatives, friends, husband	32	84.2
Trial and error	23	60.5
Professional sources: cookbooks, home economics courses, cooking schools, Home Dem. Clubs, leaflets, USDA publications	22	57.9
News media and demonstrations: magazines, newspapers, radio, TV, store displays	14	36.8

*Multiple answers.

**Percentage of 38 respondents.

spondents rated both Choice and Standard grades on all factors as "liked it very much" or "liked it slightly." However, there were differences in acceptance scores between grades and among cuts within a grade for each cooking method (Figures 1 and 2).

For cuts cooked by dry heat—broiling steaks and oven roasts—Choice grade rated significantly* better than Standard grade for ratings of

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*Chi-square test—Significance was determined at the 95 percent level (or .05 level of probability), which means that the rating differences could have occurred by chance 1 out of 20 times.

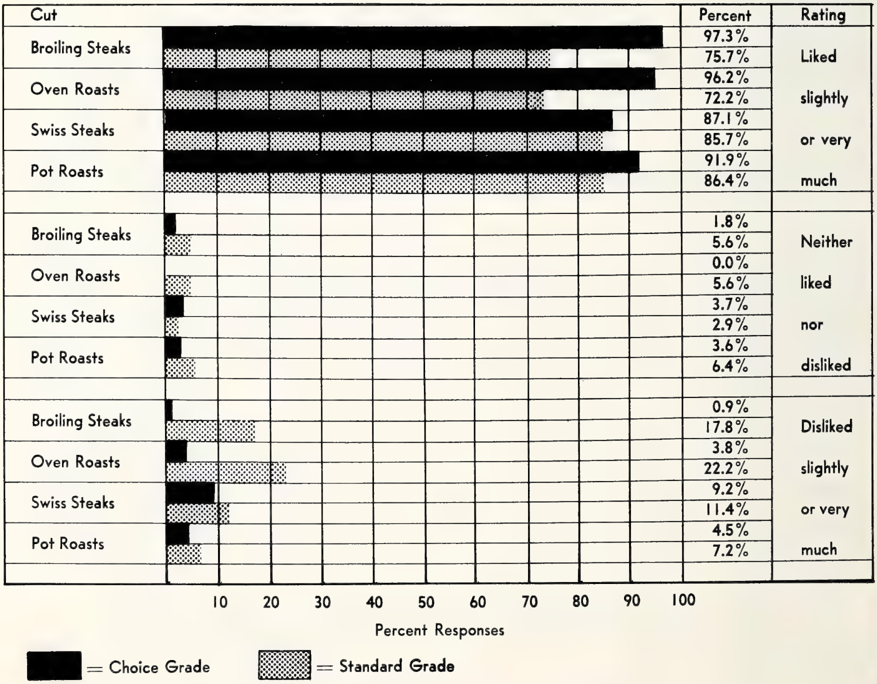

FIG. 1.—Consumers' Evaluation of Tenderness of Prefabricated Beef. (Source of data: Appendix Tables 1-8.)

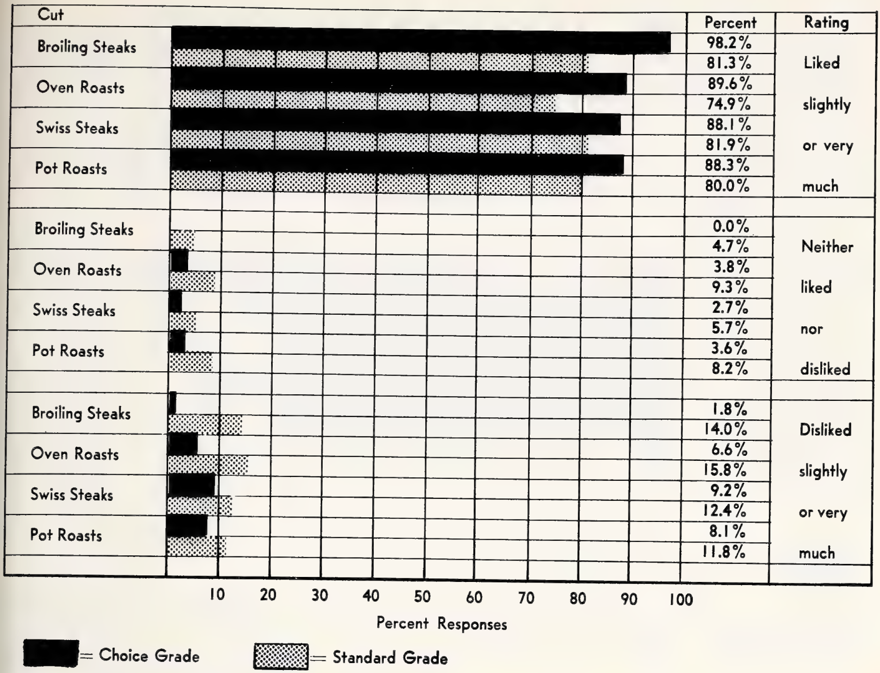

FIG. 2.—Consumers' Evaluation of General Acceptance of Prefabricated Beef. (Source of data: Appendix Tables 1-8.)

tenderness and general liking. For broiling steaks all factors showed a significant difference between grades. High Warner-Bratzler* shear values for the loin muscle of some of the Standard grade carcasses corroborated the lower panel ratings for tenderness and general acceptability of the Standard grade.

There were no significant differences in ratings of any of the factors rated in those cuts cooked by moist heat—pot roasts and swiss steaks—when the two grades were compared. Moist heat would minimize the differences in tenderness between the two grades and, consequently, the tenderness and general acceptability ratings.

Comparison of Boneless Cuts to Similar Cuts with Bone

A majority of the respondents indicated that they liked the prefabricated beef better than similar cuts with bone. There was little difference between grades except for broiling steaks; 89 percent preferred prefabricated Choice broiling steaks to the conventional cuts, compared with only 67 percent who preferred Standard broiling steaks to conventional cuts (Appendix Table 9).

Respondents' Willingness to Buy Similar Cut if Available

Approximately three-fourths of the respondents stated that they would be willing to buy prefabricated beef if it were available in retail stores. Prefabricated Choice broiling steaks gained an overwhelming acceptance by the respondents. Ninety-six percent said they would be willing to buy this cut in a retail store if it were available. However, only 79 percent said they would be willing to buy the Standard grade. The difference in acceptance between the two grades was significant. There was little difference in acceptance between grades for the other cooking methods (Figure 3).

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*Test for tenderness with high shear values indicating less tender meat.

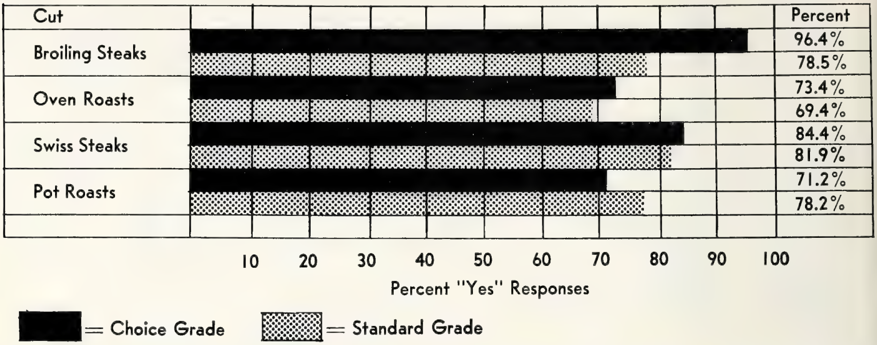

FIG. 3.—Respondents' Willingness to Buy Cuts Similar to Prefabricated Beef Tested. (Source of data: Appendix Table 10.)

Other Reactions

Space was provided on the rating sheet for comments. In those comments made, oven roasts and pot roasts had a majority of negative comments for both Choice and Standard grades. "Too much fat" or "too much waste" were the most common. Seventy-five percent of those commenting on the Choice grade broiling steaks made favorable comments, and 70 percent made favorable comments about the Standard grade. A little more than half of those commenting on the swiss steaks made favorable comments.

Overall Opinion

Each homemaker was interviewed again upon completion of the evaluation phase of the study and was asked her overall opinion of beef cut in this manner. Thirty homemakers, or approximately 80 percent, expressed views that were interpreted as being satisfactory, 3 were indifferent, 4 expressed unsatisfactory opinions, and 1 respondent said the prefabricated beef was extremely unsatisfactory (Table 6).

Some of the reasons given for satisfactory overall opinions were economy, tenderness, attractiveness, and ease in cooking, carving, and storing. Reasons for unsatisfactory opinions were "meat was tough," "bone gives flavor," and "too much fat" (Table 7). Most of the unsatisfactory comments concerned factors which probably would have been present if the meat had been sold as a similar cut with bone.

TABLE 6.—Respondents' Overall Opinions of Boneless Beef

Opinion	Number	Percent
Extremely satisfactory	8	21.1
Very satisfactory	13	34.2
Satisfactory	9	23.7
Indifferent	3	7.9
Unsatisfactory	4	10.5
Very unsatisfactory	0	0.0
Extremely unsatisfactory	1	2.6

TABLE 7.—Reasons Given by Respondents for Their Overall Opinions of Boneless Beef

Reason	Number*	Percent**
Economical	19	50.0
Flavor good	11	29.0
Tough	9	23.7
Tender	8	21.0
Bone gives flavor	8	21.0
Too much fat	7	18.4
Carves easily	5	13.2
Well trimmed	4	10.5
Easy to cook	3	7.9
Easy to handle, store	3	7.9
Looks more attractive	2	5.3
Well cut	2	5.3
Used to heavy beef	2	5.3
Prefer fat for juiciness	1	2.6
Tired of it	1	2.6
Quality was better in first batch	1	2.6
Always have eaten lighter beef	1	2.6

*Total number of reasons given.
**Percentage of 38 respondents.

Conclusions

Acceptability ratings for all cuts and grades of the frozen prefabricated beef were high. This panel of high income families was accustomed to buying Choice and Good grade beef in local supermarkets. Their general acceptance of the Standard grade prefabricated beef, especially cuts cooked by moist heat, may have implications for wider use of Sandard grade beef.

This study indicates that prefabricated beef, especially broiling steaks, would be highly acceptable to high income consumers. It suggests that successful marketing of prefabricated beef would depend upon consumer awareness of the advantages due to elimination of bone and exterior fat.

APPENDIX TABLE 1.—Rating of All Factors of Oven Roasts, Choice Grade

Rating	Tenderness		Flavor		Juiciness		General Evaluation	
	No.	Percent	No.	Percent	No.	Percent	No.	Percent
1. Liked it very much	74	70.5	79	75.2	69	65.7	70	66.7
2. Liked it slightly	27	25.7	19	18.1	25	23.8	24	22.9
3. Neither liked nor disliked	0	0.0	3	2.9	6	5.7	4	3.8
4. Disliked it slightly	4	3.8	3	2.9	5	4.8	4	3.8
5. Disliked it very much	0	0.0	1	0.9	0	0.0	3	2.8
No answer	0	0.0	0	0.0	0	0.0	0	0.0
Total	105	100.0	105	100.0	105	100.0	105	100.0

APPENDIX TABLE 2.—Rating of All Factors of Oven Roasts, Standard Grade

Rating	Tenderness		Flavor		Juiciness		General Evaluation	
	No.	Percent	No.	Percent	No.	Percent	No.	Percent
1. Liked it very much	52	48.1	52	48.2	50	46.3	49	45.3
2. Liked it slightly	26	24.1	36	33.3	34	31.5	32	29.6
3. Neither liked nor disliked	6	5.6	8	7.4	12	11.1	10	9.3
4. Disliked it slightly	16	14.8	9	8.3	7	6.5	10	9.3
5. Disliked it very much	8	7.4	2	1.9	4	3.7	7	6.5
No answer	0	0.0	1	0.9	1	0.9	0	0.0
Total	108	100.0	108	100.0	108	100.0	108	100.0

APPENDIX TABLE 3.—Rating of All Factors of Pot Roasts, Choice Grade

Rating	Tenderness		Flavor		Juiciness		General Evaluation	
	No.	Percent	No.	Percent	No.	Percent	No.	Percent
1. Liked it very much	75	67.6	73	65.8	72	64.9	61	55.0
2. Liked it slightly	27	24.3	27	24.3	29	26.1	37	33.3
3. Neither liked nor disliked	4	3.6	5	4.5	2	1.8	4	3.6
4. Disliked it slightly	5	4.5	5	4.5	6	5.4	7	6.3
5. Disliked it very much	0	0.0	1	0.9	1	0.9	2	1.8
No answer	0	0.0	0	0.0	1	0.9	0	0.0
Total	111	100.0	111	100.0	111	100.0	111	100.0

APPENDIX TABLE 4.—Rating of All Factors of Pot Roasts, Standard Grade

Rating	Tenderness		Flavor		Juiciness		General Evaluation	
	No.	Percent	No.	Percent	No.	Percent	No.	Percent
1. Liked it very much	62	56.4	59	53.7	60	54.5	51	46.4
2. Liked it slightly	33	30.0	34	30.9	33	30.0	37	33.6
3. Neither liked nor disliked	7	6.4	9	8.2	8	7.3	9	8.2
4. Disliked it slightly	2	1.8	4	3.6	5	4.6	7	6.4
5. Disliked it very much	6	5.4	4	3.6	4	3.6	6	5.4
No answer	0	0.0	0	0.0	0	0.0	0	0.0
Total	110	100.0	110	100.0	110	100.0	110	100.0

APPENDIX TABLE 5.—Rating of All Factors of Broiling Steaks, Choice Grade

Rating	Tenderness		Flavor		Juiciness		General Evaluation	
	No.	Percent	No.	Percent	No.	Percent	No.	Percent
1. Liked it very much	94	84.7	97	87.4	98	88.3	102	91.9
2. Liked it slightly	14	12.6	12	10.8	12	10.8	7	6.3
3. Neither liked nor disliked	2	1.8	2	1.8	1	0.9	0	0.0
4. Disliked it slightly	1	0.9	0	0.0	0	0.0	1	0.9
5. Disliked it very much	0	0.0	0	0.0	0	0.0	1	0.9
No answer	0	0.0	0	0.0	0	0.0	0	0.0
Total	111	100.0	111	100.0	111	100.0	111	100.0

APPENDIX TABLE 6.—Rating of All Factors of Broiling Steaks, Standard Grade

Rating	Tenderness		Flavor		Juiciness		General Evaluation	
	No.	Percent	No.	Percent	No.	Percent	No.	Percent
1. Liked it very much	60	56.1	74	69.2	66	61.7	64	59.8
2. Liked it slightly	21	19.6	20	18.7	25	23.4	23	21.5
3. Neither liked nor disliked	6	5.6	6	5.6	4	3.7	5	4.7
4. Disliked it slightly	12	11.2	4	3.7	7	6.6	11	10.3
5. Disliked it very much	7	6.6	1	0.9	4	3.7	4	3.7
No answer	1	0.9	2	1.9	1	0.9	0	0.0
Total	107	100.0	107	100.0	107	100.0	107	100.0

APPENDIX TABLE 7.—Rating of All Factors of Swiss Steaks, Choice Grade

Rating	Tenderness		Flavor		Juiciness		General Evaluation	
	No.	Percent	No.	Percent	No.	Percent	No.	Percent
1. Liked it very much	78	71.5	80	73.4	66	60.5	75	68.8
2. Liked it slightly	17	15.6	21	19.3	22	20.2	21	19.3
3. Neither liked nor disliked	4	3.7	2	1.8	10	9.2	3	2.7
4. Disliked it slightly	5	4.6	1	0.9	6	5.5	6	5.5
5. Disliked it very much	5	4.6	4	3.7	4	3.7	4	3.7
No answer	0	0.0	1	0.9	1	0.9	0	0.0
Total	109	100.0	109	100.0	109	100.0	109	100.0

APPENDIX TABLE 8.—Rating of All Factors of Swiss Steaks, Standard Grade

Rating	Tenderness		Flavor		Juiciness		General Evaluation	
	No.	Percent	No.	Percent	No.	Percent	No.	Percent
1. Liked it very much	63	60.0	70	66.7	59	56.2	60	57.1
2. Liked it slightly	27	25.7	22	21.0	26	24.8	26	24.8
3. Neither liked nor disliked	3	2.9	5	4.8	7	6.7	6	5.7
4. Disliked it slightly	8	7.6	6	5.7	11	10.5	12	11.4
5. Disliked it very much	4	3.8	1	0.9	1	0.9	1	1.0
No answer	0	0.0	1	0.9	1	0.9	0	0.0
Total	105	100.0	105	100.0	105	100.0	105	100.0

APPENDIX TABLE 9.—Comparison of Boneless Cut to Similar Cut with Bone Used Previously, All Cuts

	Oven Roast				Pot Roast				Broiling Steak				Swiss Steak			
	Choice		Standard		Choice		Standard		Choice		Standard		Choice		Standard	
Rating	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1. Liked it very much better	51	48.6	46	42.6	54	48.7	50	45.5	83	74.8	53	49.5	53	48.7	55	52.4
2. Liked it slightly better	22	20.9	21	19.4	23	20.7	22	20.0	16	14.4	19	17.8	24	22.0	18	17.1
3. Liked it about the same	14	13.3	15	13.9	14	12.6	17	15.5	6	5.4	13	12.1	20	18.4	15	14.3
4. Liked it less than other	10	9.5	13	12.0	16	14.4	12	10.9	2	1.8	14	13.1	7	6.4	13	12.4
5. Disliked it	5	4.8	7	6.5	0	0.0	6	5.5	1	0.9	5	4.7	2	1.8	1	0.9
6. Don't usually buy this cut	3	2.9	2	1.9	3	2.7	1	0.9	3	2.7	3	2.8	2	1.8	1	0.9
No answer	0	0.0	4	3.7	1	0.9	2	1.8	0	0.0	0	0.0	1	0.9	2	2.0
Total	105	100.0	108	100.0	111	100.0	110	100.0	111	100.0	107	100.0	109	100.0	105	100.0

APPENDIX TABLE 10.—Respondent's Indication of Willingness to Buy a Similar Cut if Available

	Oven Roast				Pot Roast				Broiling Steak				Swiss Steak			
	Choice		Standard		Choice		Standard		Choice		Standard		Choice		Standard	
Response	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent
1. Yes	77	73.4	75	69.4	79	71.2	86	78.2	107	96.4	84	78.5	92	84.4	86	81.9
2. No	26	24.8	30	27.8	27	24.3	23	20.9	4	3.6	20	18.7	13	11.9	14	13.3
3. Maybe	1	0.9	2	1.9	3	2.7	0	0.0	0	0.0	1	0.9	3	2.8	3	2.9
No answer	1	0.9	1	0.9	2	1.8	1	0.9	0	0.0	2	1.9	1	0.9	2	1.9
Total	105	100.0	108	100.0	111	100.0	110	100.0	111	100.0	107	100.0	109	100.0	105	100.0

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CONSUMER ACCEPTANCE STUDIES

II. GROUND BEEF OF VARYING FAT COMPOSITION

SCHOOL OF HOME
ECONOMICS
and
DEPARTMENTS
of
ANIMAL SCIENCE and
AGRICULTURAL ECONOMICS AND
AGRIBUSINESS

HELEN M. LAW
MARIANNE S. BEESON
ALMA BETH CLARK
AUTTIS M. MULLINS
GENE E. MURRA

Louisiana State University and
Agricultural and Mechanical College
Agricultural Experiment Station
Doyle Chambers, Director

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Southern Regional Research Project SM-19

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Consumer Acceptance Studies

II. Ground Beef of Varying Fat Composition

HELEN M. LAW,[1] MARIANNE S. BEESON,[1] ALMA BETH CLARK,[1]
AUTTIS M. MULLINS,[2] GENE E. MURRA[3]

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Introduction

Ground beef is one of the most popular items on the retail market. It accounted for 31 percent of the total pounds of beef purchased during the period of a USDA survey of food consumption (*7*). Woods and Nettles (*8*) found ground beef ranked second only to chicken in the number of times it was suggested as the appropriate meat for various meal situations.

Considerable research has been carried out concerning consumer evaluation of specific beef cuts. However, little work has been done with ground beef to determine quality characteristics preferred by consumers. Two recent studies have dealt specifically with the fat content of ground beef. Glover (*6*) hypothesized that degree of leanness is the basic criterion by which consumers judge quality in ground beef. Using a sample composed of 150 families in each of two cities, he found that ground beef containing 20 percent fat was preferred over 16, 25, and 30 percent fat levels for hamburger-type patties.

Cole, Ramsey, and Odom (*4*) investigated the effect of fat content on palatability of broiled ground beef. A five-member taste panel and six-member family panel indicated that desirable tenderness and juiciness were best obtained with broiled ground beef patties of at least one-third fat content. The authors suggested that leaner ground beef may be more desirable for other uses, such as meat loaf and sauces, where fat from the ground beef is not drained off as it is in broiling.

The trend toward centralized processing and packaging of ground beef for distribution to retail outlets makes it important to know the fat levels consumers prefer in ground beef. If ground beef of the most acceptable fat level and consistent uniformity is offered, greater consumer satisfaction and subsequent increased sales will benefit all phases of beef marketing.

The present study is based on the following hypotheses:

1. Degree of leanness is the fundamental feature consumers associate with quality in ground beef.
2. The amount of fat that is acceptable to the consumer is influenced by the way the ground beef is prepared. Less fat is acceptable in dishes in which the fat becomes a part of the final product,

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[1] School of Home Economics.

[2] Department of Animal Science.

[3] Department of Agricultural Economics and Agribusiness.

such as spaghetti sauce, than is acceptable in hamburger patties where the fat is drained off.

3. Low income families differ from medium and high income families in the way they evaluate the acceptability of various fat levels in ground beef. High income families tend to be more discriminating.

Procedure

Sampling

The consumer panel, consisting of 122 families in Baton Rouge, Louisiana, was obtained by a random sampling process from addresses appearing in a commercially prepared directory (5). This directory lists all the streets in Baton Rouge, the number of residences on each street, and the house numbers and names of occupants. A running total of the number of residences on all streets was made; then a random number table was used to choose the desired number of streets from which to obtain the required number of families. In this way every section of Baton Rouge had an equal chance to be represented in the sample. The sample size for selected streets was 20 percent of the number of residences on a street, with a maximum sample of ten residences. Addresses of the primary sample were picked by random number, and groups of five alternates were picked in a similar manner. Existence of a family situation was the only requirement for participation.

Interviewing

Homemakers were interviewed by members of the Home Economics Marketing Research staff in the spring of 1964. A detailed questionnaire was used to provide information on such family characteristics as race, size of family, ages of family members, occupations and education of husband and wife, and family income. These were used to study their effect on consumer acceptance of various fat levels in ground beef. Information on buying practices and utilization of ground beef also was obtained.

Conducting the Panel Test

In order to determine the fat levels acceptable for two forms of ground beef, families were asked to buy, at a reduced price, five packages of frozen patties and five packages of frozen bulk ground beef in amounts requested by each family. Each package contained a rating sheet (Appendix A) on which the respondents were asked to rate, according to a 9-point hedonic scale, the following characteristics: *color before cooking, shrinkage, general cooking qualities, juiciness, flavor,* and *general acceptability.* Space was available for comments. Ground beef of three different fat levels — 15 percent, 25 percent, and 35 percent — was rated by each family. Randomly selected replicates of two of the three fat levels were included to make up five packages of patties and five packages of bulk ground beef for each family. Glover's study (6) indicated that cooking methods did not affect results. Therefore, families in the present study were not asked to use any special cooking method, but were to use the patties as hamburgers and to indicate the cooking method used. The bulk form was to be used for any ground beef dish the family desired except as hamburgers.

Obtaining the Desired Fat Composition

Ground beef of varying fat composition was prepared by a commercial meat packer, under the direction of the Animal Science Department, from Utility grade beef chuck, and suet from Good and Choice grade carcasses. The 15 percent fat level was obtained without the addition of trim fat, the 25 percent fat level by the addition of approximately 12 pounds of suet per 100 pounds ground chuck, and the 35 percent fat level by the addition of approximately 21 pounds of suet per 100 pounds of ground chuck. Fat levels were ascertained during the final grinding and mixing operation by a rapid method of fat determination utilizing the Babcock fat testing principle. The fat content was adjusted to within plus or minus 1 percent of the desired levels by this method.

One-half of each formulation was made up into patties — four per pound. The remainder was packaged as bulk ground beef. All the ground beef was wrapped in laminated freezer paper and quick-frozen prior to delivery.

Statistical Analysis

The mean (or average) hedonic ratings for each characteristic and each form and fat level were computed, as well as the analysis of variance, by the IBM 1620 computer. To facilitate the analysis, only those families with complete returns were used (110 families). Where more than one answer for each type was given, one was randomly chosen.

Characteristics of the Family Panel

Size of Families

A consumer panel, consisting of 112 white families and 10 nonwhite families, was selected in Baton Rouge, Louisiana. Families ranged in size from 2 to 10 persons, with an average family size of 4.8 persons. This was slightly larger than the average population per household in Baton Rouge, which in 1960 was 3.43 persons (*3*) .

Income

Three income categories were used in this study — low (under $5,000), medium ($5,000 to $10,000), and high ($10,000 or more). Twenty-two percent of the families were in the low income group, 53 percent in the medium income group, and 25 percent in the high income

TABLE 1.—Characteristics of the Family Panel

Classification	Number	Percent*
Family Income		
Less than $5,000	27	22.1
$5,000 to $10,000	65	53.3
$10,000 or more	30	24.6
Race		
White	112	91.8
Nonwhite	10	8.2
Total Number of Persons in Household		
Two-Four	62	50.8
Five-Seven	53	43.5
Eight-Ten	7	5.7
Number of Persons under 6 years		
One	37	30.3
Two	24	19.7
Three	6	4.9
Four	3	2.5
None	52	42.6
Number of Persons 6-11 years		
One	29	23.8
Two	22	18.0
Three	8	6.5
Four	3	2.5
Five	1	0.8
None	59	48.4
Number of Persons 12-19 years		
One	16	13.1
Two	18	14.8
Three	9	7.4
Four	2	1.6
None	77	63.1
Occupation of Husband**		
Professional	58	50.0
Clerical and Sales	12	10.3
Craftsmen and Operatives	36	31.1
Service Workers and Laborers	4	3.4
Retired, Unemployed, Welfare	6	5.2
Age of Husband**		
20 to 30 years	25	21.6
30 to 50 years	73	62.9
50 years or older	18	15.5
Age of Homemaker		
20 to 30 years	36	29.5
30 to 50 years	68	55.8
50 years or older	18	14.7
Education of Husband**		
Grade School	10	8.6
High School	37	31.9
College	45	38.8
Postgraduate Work	19	16.4
Other: Business or Trade School	5	4.3
Education of Homemaker		
Grade School	6	4.9
High School	49	40.2
College	44	36.0
Postgraduate Work	4	3.3
Other: Business or Trade School	18	14.8
No Formal Education	1	0.8

*Percentages in each classification total 100.

**Based on 116. Six respondents had no husbands.

group (Table 1). This compares with 43 percent, 39 percent, and 18 percent in the low, medium, and high income groups, respectively, for Baton Rouge (1960 census) (*3*).

Occupations of Husbands

Half of the husbands were classified (*2*) in the professional, technical, or managerial fields. Another one-third were in the craftsmen, foremen, or operatives group, while clerical and sales workers accounted for one-tenth of the total. Four were service workers or laborers. Six of the husbands were retired or unemployed, and six of the respondents had no husband.

Occupations of Homemakers

The majority of the women were full-time homemakers. This is to be expected since the interviewing took place during the daytime hours. Only 3 percent worked outside the home full-time, and another 12 percent worked part-time. Clerical and sales work were the occupations listed most often by women who had full- or part-time positions.

Age of Respondents

One-fifth of the husbands and one-third of the homemakers were between 20 and 30 years of age. Over half of the homemakers and husbands were between the ages of 30 and 50 years. Fifteen percent of the homemakers and husbands were 50 years of age or older. The average age of this sample was slightly younger than the average of the adult Baton Rouge population (1960 census) (*3*).

Education of Husbands

East Baton Rouge Parish leads all other parishes in the state in the level of education, with adults having completed a median of 11.9 years of schooling (*1*). In this study, approximately one-third of the husbands had some high school education or had finished high school, while over half had some college education or were college graduates. Nineteen of these had done some graduate work or had received advanced degrees. Five husbands had received business college or trade school training and ten had only an elementary education.

Education of Homemakers

Two-fifths of the homemakers had received some high school education or had completed high school. A similar number had some college training or had completed college. Eighteen listed business college or trade school as part of their education. Six homemakers had an elementary education while one had no formal education.

Consumer Habits of Buying and Using Ground Beef

Homemakers were asked about their habits and preference for buying and using ground beef to determine their concept of ground beef and the influence this has on the acceptability of various types.

Use of Ground Beef

Ground beef was a popular form of beef in the diets of the families in the study. Eighty-eight percent indicated that they served ground beef in some way two or more times per week. Hamburgers were by far the most common form of ground beef served, with meat balls, meat sauce, and meat loaf following in popularity (Table 2).

TABLE 2.—Method and Frequency of Preparation of Ground Beef by Respondents

Form	Two or more times per week		One time per week		One or two times per mo.		Occasionally		Never	
	No.	%	No.	%	No.	%	No.	%	No.	%
Estimated times ground beef served	107	87.7	13	10.7	2	1.6	0	0.0	0	0.0
Hamburgers	41	33.6	54	44.3	25	20.5	1	0.8	1	0.8
Meat loaf	1	0.8	20	16.4	60	49.2	32	26.2	9	7.4
Chili	0	0.0	7	5.7	22	18.0	40	32.8	53	43.4
Meat balls	4	3.3	37	30.3	46	37.7	10	8.2	25	20.5
Ground beef casseroles	0	0.0	5	4.1	31	25.4	29	23.8	56	45.9
Meat sauce	0	0.0	19	15.6	49	40.2	27	22.1	27	22.1
Other dishes	1	0.8	5	4.1	33	27.0	24	19.7	7	5.7

Forms Purchased

Almost half of the respondents stated that they usually purchased ground beef in the pre-packaged, bulk form, while about one-third usually had beef ground to order. Fifteen bought a side or quarter of beef or raised their own beef. Very few ever purchased frozen or fresh ground beef patties (Table 3).

TABLE 3.—Frequency Respondents Purchase Ground Beef in Different Forms

Form	Always		Most of the time		About half the time		Rarely		Never	
	No.	%	No.	%	No.	%	No.	%	No.	%
Not pre-packaged, bulk	7	5.7	6	4.9	6	4.9	19	15.6	84	68.9
Pre-packaged, bulk	36	29.6	22	18.0	16	13.1	21	17.2	27	22.1
Ground to order	17	13.9	16	13.1	12	9.8	18	14.8	59	48.4
Frozen patties	0	0.0	1	0.8	3	2.5	34	27.9	84	68.8
Fresh patties	2	1.6	0	0.0	5	4.1	12	9.8	103	84.5
Side or quarter of beef	15	12.3	0	0.0	0	0.0	0	0.0	107	87.7

Who Purchases Ground Beef and Where

In almost all of the families, the homemaker purchased most of the meat. Over half of the respondents bought ground beef at large national chain stores, while almost one-fifth obtained ground beef from a local meat packer or wholesaler. Retail stores are maintained by many of these wholesalers. The remainder of the respondents bought at local chain stores, local grocery stores, or meat markets (Table 4).

Product Characteristics

Families were asked to rank selected characteristics they used in purchasing ground beef. The color of the meat was rated most important, with leanness, label, and price following in order of importance. Color was usually thought to be an indication of the amount of fat present. Therefore, leanness appears to be the quality characteristic most desired in ground beef. Price does not appear to be a primary factor, because of the relatively low price of ground beef compared to other beef cuts (Table 5).

Preferences

Most of the ground beef made from available trimmings and retailing below 50 cents per pound is labeled as "ground beef" in the Baton Rouge area. The name "hamburger" is seldom used. Ground chuck and ground round usually are marketed as such.

Homemakers were asked which kind of ground beef they preferred and which they usually bought for two family dishes, hamburgers and meat sauce for spaghetti. This was done to test the hypothesis that ground beef with less fat is preferred for dishes in which the fat becomes a part of the final product, such as meat sauce. Homemakers made little distinction between types of ground beef preferred for the preparation of hamburgers and that preferred for meat sauce, as indicated in Table 6. In comparing preferences with what was actually purchased for the two uses, some differences are evident. Lower prices

TABLE 4.—Where Respondents Usually Purchase Ground Beef

Type store	Number	Percent
National chain	66	54.1
Local chain	7	5.7
Local meat market	4	3.3
Local grocery	9	7.4
Local meat packer or wholesaler	23	18.9
Voluntary chain	11	9.0
Raise own beef	2	1.6

TABLE 5.—Average Rating for Product Characteristics Used in Purchasing Ground Beef

Characteristic	Average rating	Number of respondents rating
Color	1.86	122
Leanness	2.38	122
Label	2.83	118
Price	3.08	120
Other	3.58	19

(Ratings from 1 to 5 were possible, 1 being the highest rating.)

TABLE 6.—Form of Ground Beef Preferred and Bought for Two Uses

Form	Preferred for meat sauce		Bought for meat sauce		Preferred for hamburgers		Bought for hamburgers	
	No.	%	No.	%	No.	%	No.	%
Ground beef or hamburger	26	21.3	48	39.3	28	23.0	49	40.2
Ground chuck	44	36.1	51	41.8	48	39.3	49	40.2
Ground round	49	40.2	20	16.4	45	36.9	22	18.0
Combination of ground beef and ground chuck	2	1.6	2	1.6	1	0.8	2	1.6
Combination of ground chuck and ground round	1	0.8	1	0.8	0	0.0	0	0.0

of "ground beef" and "ground chuck" was the main reason given for their purchase even though "ground round" was preferred.

More than half of the respondents preferred and also bought "ground round" and "ground chuck." "Better flavor" and "less fat" were reasons given for these preferences. Consumers consistently purchased "ground round" and "ground chuck" because they could be assured of more uniformity than if they purchased "ground beef."

Planning Ahead

The majority of the homemakers did not have a specific use planned for the ground beef at the time of purchase. Most bought one kind of ground beef consistently regardless of the dish to be prepared. Many homemakers purchased several packages at one time and stored them in their freezers. However, as the homemakers did not have a specific use planned for the ground beef, it is probable that the most expensive form of ground beef was often being used where a cheaper form might be just as suitable.

Analyzing Ground Beef from Selected Stores

In order to evaluate the composition of ground beef sold in Baton Rouge, samples labeled "ground beef" or "hamburger" and "ground chuck" were purchased from eight stores from all sections of the city. These stores were representative of those where the respondents shopped. The samples were analyzed for moisture, fat, protein, and ash. The chemical analysis showed a wide range of fat content; "ground beef" or "hamburger" varied from 14.5 percent to 35.5 percent, and "ground chuck," from 7.6 percent to 24.8 percent fat. The meat market managers were interviewed for their estimate of the amount of fat in their ground beef. The managers claimed from 20 to 30 percent fat for the "ground beef" and from zero to about 10 percent fat for "ground chuck." Only one said his ground beef was chemically analyzed periodically.

Few food stores at present are using objective methods to ascertain the lean-fat composition of ground beef. Objective methods would be required if they are to fabricate ground beef of uniform quality.

Consumer Evaluation of Ground Beef

Average Panel Ratings for Three Fat Levels

Respondents in this study consistently preferred ground beef with the lowest fat content. Of the three fat levels tested, 15 percent ground beef was rated best, followed in order by 25 percent and 35 percent fat levels (Table 7). For all characteristics except *juiciness,* the differences among fat levels were highly significant ($P<.01$).* Although the ratings decreased as the fat content increased for all of the characteristics rated, respondents were more critical of factors associated with the appearance of the meat prior to cooking and with the cooking qualities (*shrinkage, color before cooking, general cooking qualities,* and *general liking*). They were less discriminating in rating eating characteristics (*flavor* and *juiciness*) of the meat.

TABLE 7.—Mean Hedonic Ratings of Ground Beef of Three Fat Levels*

Fat content	Color before cooking	Shrinkage	General cooking qualities	Juiciness	Flavor	General rating
15% Patties	2.9	2.5	2.8	3.9	3.0	3.3
25% Patties	3.8	3.5	3.4	3.9	3.4	3.7
35% Patties	4.4	5.5	4.3	4.0	3.7	4.3
15% Bulk	2.5	2.7	2.5	2.8	2.5	2.7
25% Bulk	3.5	3.8	3.4	3.2	2.9	3.4
35% Bulk	3.7	4.9	3.8	3.6	3.2	4.0
15% (Overall)	2.7	2.6	2.6	3.3	2.7	3.0
25% (Overall)	3.6	3.6	3.4	3.5	3.1	3.5
35% (Overall)	4.1	5.2	4.0	3.8	3.5	4.1

1.0 = Highest possible rating.

*To facilitate analysis of variance by the computer, only those families with complete returns were used in this analysis (110 families). Where more than one answer for each type was given, one was randomly chosen.

Bulk Versus Patties

With two exceptions (15 percent and 25 percent *shrinkage*), the bulk form of ground beef was rated slightly higher than the patty form. The differences between bulk form and patty form were highly significant ($P<.01$) for all characteristics except *shrinkage* and *general cooking qualities.* The greatest difference between bulk and patty forms was found in ratings of *juiciness.* Bulk form was rated much higher than the patty form for this characteristic. This may have been due to a loss of juice in the compressing of the beef to make the patties.

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*Significance was determined by analysis of variance at the 99 percent level (or .01 level of probability), which means that the rating differences could have occurred by chance 1 out of 100 times.

Relationship of Method of Preparation to Average Panel Ratings

The method of preparation had little effect on the average ratings for the different fat levels of ground beef. The lowest fat level was rated best for all methods of preparation, whether fat was incorporated into the dish, as in the bulk form, or drained off, as in the patty form. This indicates that consumers probably would always buy ground beef of the same fat content regardless of its use.

Other Reactions

The rating sheets included space for comments for each characteristic rated. Generally, as the percentage of fat increased, there were fewer favorable comments and more unfavorable comments. The major exception to this was in the comments on *juiciness* of the patties. Unfavorable comments on the lack of juiciness were given for all fat levels of patties. Apparently, the patties lost some of their juiciness when they were compressed. The bulk form received more favorable comments for all characteristics and all fat levels than did the patty form. Comments on fat content appeared in connection with all of the characteristics rated. Most of these expressed dissatisfaction with the amount of fat. Thus, degree of leanness is an important criterion used in rating ground beef.

Influence of Family Characteristics on Average Panel Ratings

The mean (or average) hedonic ratings for each fat level and each form (bulk and patties) were correlated with some of the family characteristics to determine their effect on the acceptability ratings (Appendix Tables 1 through 5).

Family Income

In previous consumer panel work, low income respondents have tended to be less critical of test foods than have high income respondents. In this study of acceptability of different fat levels in ground beef, the above tendency was observed only in rating the 35 percent fat level (Appendix Table 1). The lowest income group gave higher acceptance ratings for the 35 percent fat levels than the other income groups and made little distinction among the three fat levels. This was generally true for all of the characteristics rated. No definite patterns were observed in the ratings of the ground beef with 15 percent and 25 percent fat levels.

The above results imply that income level has little effect on the acceptability of ground beef with a relatively low fat level. However, as the amount of fat is increased, high income groups tend to be more critical of a high fat level than do low income groups. This may be because the low income groups generally are accustomed to using ground beef with high fat content.

Education

The relationship of education of respondents to the average panel ratings was similar to that found between income and ratings (Appendix Tables 2 and 3). This was expected because of the usual close relationship between education and income. Generally, less distinction was made between the lowest and highest fat levels by respondents with less education compared with those with more education. Once again, the greatest difference among educational levels was in the rating of the 35 percent ground beef.

Occupation

The occupational status of respondents had little influence on the acceptability ratings. This was expected, as each occupational category represented a wide range of incomes and ages.

Age

Because of the present emphasis on the relationship of dietary fats to coronary heart disease and to general nutritional status, attempts to reduce or limit fat intake are being made by many people. Older people, in particular, are often advised to limit their consumption of food fats. It was expected that the older group (50 years or older) would be more critical of high fat ground beef than the younger groups. However, the opposite was true (Appendix Tables 4 and 5). That is, the younger age groups were more critical of a high fat level than was the oldest age group, which made little distinction between fat levels. The indication is that the older age group either did not recognize the high fat content of some of the ground beef or did not object to it if they did recognize it.

Summary and Conclusions

One hundred and twenty-two families in Baton Rouge, Louisiana, rated ground beef of three fat levels and in two forms. The families consistently preferred the lowest fat level (15 percent) for all of the six characteristics rated. The differences among the fat levels were highly significant ($P<.01$) for all characteristics except *juiciness.* Respondents were especially critical of the pre-cooked appearance and cooking qualities of the ground beef. There was little variation in ratings of the eating qualities among the three fat levels tested.

The bulk form was favored slightly over the patty form for each level of fat tested. This was especially true of the ratings of *juiciness.* The differences were highly significant ($P<.01$) for all characteristics except *shrinkage* and *general cooking qualities.* There was no distinguishable effect of the method of preparation of the meat on acceptability ratings.

The lowest income families were less critical in their ratings. They made less distinction between the lowest and highest fat levels than respondents with higher income. High income families were especially critical of the 35 percent fat ground beef. As expected, a similar relationship between average ratings and educational level was observed.

During preliminary interviews, the majority of the respondents stated they usually bought "ground round" or "ground chuck" instead of "ground beef" or "hamburger" because they wanted less fat and could be assured of more consistent quality. When samples of ground beef from eight food stores in Baton Rouge were analyzed, it was found that the fat content of the ground beef did vary widely. Few stores regularly determine lean-fat ratios of ground beef by objective methods, and thus, fat content would naturally vary. If, as respondents in this study stated, consumers look for low fat and consistent quality in ground beef, it would be necessary for retailers to use more objective methods of determining lean-fat ratios.

This study indicates that consumers prefer ground beef with a low fat content. Consumers associate leanness with quality. Although the 15 percent fat level was preferred in this study, it was not ascertained how much more consumers would be willing to pay for the low fat ground beef compared with what they would pay for high fat ground beef. This may depend somewhat on the income, education, age, and occupational status of the consumer.

By knowing his customers, a retailer can supply the type of ground beef which most of them prefer. For example, in a high income area, the consumer will probably not be satisfied with a high fat ground beef. The retailer also must be able to supply the preferred type consistently. By offering what the customer wants, he can better satisfy his customers and increase sales.

Appendix A

Interview Schedule II

Record Number__________

Code Letter __________

Family Name ____

Date Eaten ____
(month) (day) (year)

Which way did you prepare this package of meat? Check one.

A. If in patty form:

(1) ______pan-broiled

(2) ______charcoal-broiled

(3) ______oven-broiled

(4) ______pan-fried

B. If in bulk form:

______meat loaf

______spaghetti sauce

______meat balls

______casserole

______chili

______pizza

______other____
(specify)

1. How do you rate the COLOR of this meat before it is cooked?

Excellent ☐
☐
☐
☐
☐
☐
☐
☐
Poor ☐

Comments:______________________________
____
____

2. After cooking, how do you rate the amount of SHRINKAGE?

Acceptable amount of shrinkage ☐
☐
☐
☐
☐
☐
☐
☐
Too much shrinkage ☐

Comments:______________________________
____
____

(Continued)

Schedule II
Page 2

Record Number__________
Code Letter __________

3. How do you rate the GENERAL COOKING QUALITIES of this meat?

Excellent ☐
☐
☐
☐
☐
☐
☐
☐
Poor ☐

Comments:______________________________
____
____

4. After eating the meat, how do you rate its JUICINESS?

Excellent ☐
☐
☐
☐
☐
☐
☐
☐
Poor ☐

Comments:______________________________
____
____

5. How do you rate the FLAVOR OR TASTE of this meat?

Excellent ☐
☐
☐
☐
☐
☐
☐
☐
Poor ☐

Comments:______________________________
____
____

6. IN GENERAL, how do you rate this package of meat?

Excellent ☐
☐
☐
☐
☐
☐
☐
☐
Poor ☐

Comments:______________________________
____
____

BE SURE TO MAIL THESE TWO SHEETS IN THE ENCLOSED ADDRESSED ENVELOPE AS SOON AS POSSIBLE

APPENDIX TABLE 1.—Influence of Income on Average Ratings of Ground Beef

	Color before cooking		Shrinkage		General cooking qualities		Juiciness		Flavor		General acceptability	
	Patties	Bulk	Patties	Bulk	Patties	Bulk	Patties	Bulk	Patties	Bulk	Patties	Bulk
15 Percent fat level												
Under $5,000	2.80	2.82	2.77	3.20	2.70	2.69	3.30	2.64	2.91	2.78	3.02	2.98
$5,000 to $10,000	2.77	2.45	2.46	2.58	2.81	2.48	3.55	2.64	2.71	2.29	3.05	2.50
$10,000 or more	3.10	2.50	2.50	2.22	3.12	2.53	4.59	3.02	3.86	2.64	4.04	2.80
25 Percent fat level												
Under $5,000	3.36	3.23	3.60	3.13	3.29	2.87	3.33	3.00	3.11	2.60	3.50	2.85
$5,000 to $10,000	3.92	3.41	3.90	3.61	3.67	3.53	4.14	3.24	3.44	2.87	3.90	3.41
$10,000 or more	3.55	3.23	3.30	3.70	3.40	3.21	3.77	3.28	3.51	3.10	3.53	3.34
35 Percent fat level												
Under $5,000	3.85	3.45	4.80	4.35	3.85	3.38	3.96	3.36	3.22	2.59	3.98	3.28
$5,000 to $10,000	4.57	4.12	5.62	4.84	4.57	4.01	4.22	3.60	4.02	3.51	4.68	4.19
$10,000 or more	4.24	4.20	5.34	5.54	4.38	4.46	4.50	4.28	3.96	3.88	4.53	4.61

1.00 = Highest possible rating.

APPENDIX TABLE 2.—Influence of Education of Homemaker on Average Ratings of Ground Beef

	Color before cooking		Shrinkage		General cooking qualities		Juiciness		Flavor		General acceptability	
	Patties	Bulk	Patties	Bulk	Patties	Bulk	Patties	Bulk	Patties	Bulk	Patties	Bulk
15 Percent fat level												
Grade sch., no formal ed.	1.75	3.15	2.33	3.31	2.17	2.92	2.50	2.38	2.25	2.62	2.08	2.92
High school, trade school	2.86	2.44	2.59	2.70	2.81	2.61	3.42	2.81	2.81	2.44	3.14	2.67
College	2.92	2.61	2.49	2.41	3.05	2.39	4.44	2.70	3.51	2.55	3.71	2.67
25 Percent fat level												
Grade sch., no formal ed.	3.18	1.75	3.55	1.63	2.73	2.13	2.55	1.50	2.91	1.63	3.09	1.75
High school, trade school	3.50	3.26	3.64	3.40	3.31	3.26	3.90	3.34	3.22	2.90	3.58	3.26
College	4.06	3.57	3.90	3.91	3.92	3.49	4.01	3.19	3.66	2.96	3.99	3.45
35 Percent fat level												
Grade sch., no formal ed.	2.08	2.60	4.00	2.80	2.00	1.80	2.46	1.70	2.15	1.80	1.54	2.00
High school, trade school	4.17	3.69	5.27	4.44	4.29	3.79	4.10	3.55	3.73	3.25	4.29	3.87
College	4.86	4.57	5.69	5.78	4.80	4.56	4.67	4.21	4.19	3.84	5.04	4.69

1.00 = Highest possible rating.

APPENDIX TABLE 3.—Influence of Education of Husband on Average Ratings of Ground Beef

	Color before cooking		Shrinkage		General cooking qualities		Juiciness		Flavor		General acceptability	
	Patties	Bulk	Patties	Bulk	Patties	Bulk	Patties	Bulk	Patties	Bulk	Patties	Bulk
15 Percent fat level												
Grade school	1.88	2.65	2.00	3.06	1.88	2.53	2.31	2.29	1.94	2.35	1.94	2.59
High school, trade school	2.94	2.79	2.65	2.89	3.09	2.74	3.65	2.97	3.01	2.58	3.38	2.85
College	2.83	2.37	2.55	2.37	2.87	2.44	4.12	2.69	3.23	2.46	3.45	2.59
25 Percent fat level												
Grade school	2.67	2.00	2.93	1.83	2.47	2.25	2.07	2.33	2.40	1.58	2.53	1.67
High school, trade school	4.08	3.76	4.12	3.52	3.71	3.58	4.26	3.67	3.55	3.40	4.03	3.70
College	3.67	3.25	3.55	3.75	3.59	3.29	3.97	3.05	3.46	2.74	3.73	3.21
35 Percent fat level												
Grade school	2.75	2.53	4.20	3.00	2.85	2.12	3.25	2.24	2.60	1.88	3.00	2.12
High school, trade school	4.46	4.06	5.62	4.88	4.75	3.80	4.30	3.68	4.25	3.40	4.75	4.06
College	4.57	4.31	5.45	5.27	4.54	4.50	4.46	3.99	3.89	3.71	4.62	4.49

1.00 = Highest possible rating.

APPENDIX TABLE 4.—Influence of Age of Homemaker on Average Ratings of Ground Beef

	Color before cooking		Shrinkage		General cooking qualities		Juiciness		Flavor		General acceptability	
	Patties	Bulk	Patties	Bulk	Patties	Bulk	Patties	Bulk	Patties	Bulk	Patties	Bulk
15 Percent fat level												
Under 30 years	2.84	2.28	2.67	2.47	2.84	2.28	3.83	2.54	2.95	2.23	3.38	2.57
30 to 50 years	2.83	2.62	2.48	2.64	2.94	2.66	3.86	2.88	3.18	2.64	3.39	2.74
50 years or older	2.70	2.55	2.50	2.84	2.63	2.65	3.20	2.61	2.73	2.58	2.77	2.74
25 Percent fat level												
Under 30 years	3.96	3.71	3.61	3.33	3.53	3.24	4.05	3.19	3.21	2.64	3.72	3.20
30 to 50 years	3.75	3.34	3.77	3.75	3.66	3.44	4.01	3.24	3.62	3.08	3.85	3.44
50 years or older	3.03	2.48	3.53	3.07	3.00	2.93	3.00	3.07	2.83	2.52	3.21	2.74
35 Percent fat level												
Under 30 years	4.86	4.56	5.24	4.91	4.47	4.31	3.98	3.88	3.74	3.56	4.57	4.28
30 to 50 years	4.41	4.00	5.67	5.15	4.70	4.17	4.59	3.88	4.22	3.58	4.79	4.34
50 years or older	3.00	2.93	4.48	4.00	2.90	2.79	3.42	2.82	2.55	2.54	3.20	2.93

1.00 = Highest possible rating.

APPENDIX TABLE 5.—Influence of Age of Husband on Average Ratings of Ground Beef

	Color before cooking		Shrinkage		General cooking qualities		Juiciness		Flavor		General acceptability	
	Patties	Bulk	Patties	Bulk	Patties	Bulk	Patties	Bulk	Patties	Bulk	Patties	Bulk
15 **Percent fat level**												
Under 30 years	3.02	2.38	2.95	2.65	3.10	2.43	3.98	2.68	3.21	2.40	3.48	2.75
30 to 50 years	2.74	2.48	2.39	2.44	2.85	2.49	3.91	2.78	3.10	2.47	3.37	2.56
50 years or older	2.63	2.97	2.53	3.16	2.60	2.94	3.07	2.74	2.57	2.68	2.77	3.00
25 **Percent fat level**												
Under 30 years	3.97	3.82	3.59	3.67	3.77	3.36	4.46	3.30	3.38	2.85	3.92	3.41
30 to 50 years	3.78	3.28	3.82	3.51	3.57	3.25	3.95	3.14	3.50	2.90	3.78	3.23
50 years or older	3.23	2.96	3.40	3.52	3.17	3.44	3.10	3.44	3.07	2.93	3.31	3.30
35 **Percent fat level**												
Under 30 years	4.83	4.35	5.38	5.08	4.63	4.35	4.48	4.06	4.13	3.67	4.75	4.17
30 to 50 years	4.53	4.19	5.54	5.04	4.65	4.20	4.38	3.86	4.01	3.55	4.69	4.36
50 years or older	3.00	3.11	3.29	4.21	3.35	2.86	3.61	2.68	3.03	2.64	3.33	3.04

1.00 = Highest possible rating.

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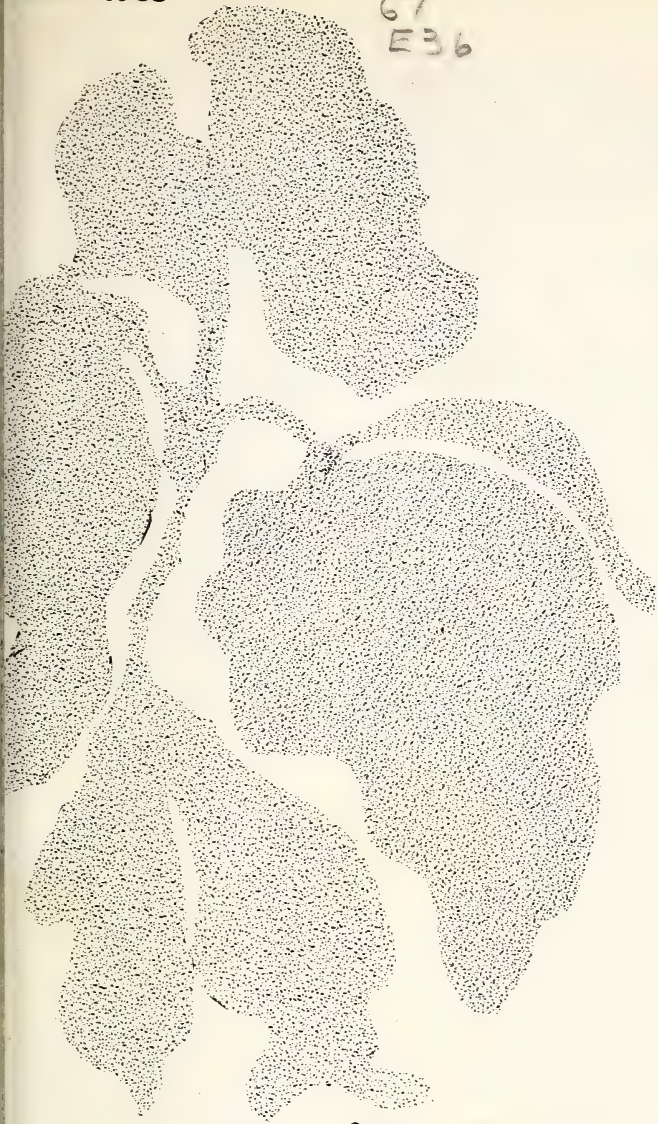

K. N. CLOWER

W. H. PATRICK, JR.

Soil Moisture Extraction and Physiological Wilting of Cotton on Mississippi River Alluvial Soils

Louisiana State University and
Agricultural and Mechanical College
Agricultural Experiment Station
Doyle Chambers, Director

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Soil Moisture Extraction and Physiological Wilting of Cotton on Mississippi River Alluvial Soils

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K. N. Clower and W. H. Patrick, Jr.[1]

Abstract

Physiological wilting of cotton on the Mississippi River floodplain soils of Northeast Louisiana was found to occur because of a shortage of available moisture at the beginning of the growing season. Because of the compact nature of these soils, winter and early spring rainfall did not penetrate below a depth of 2-3 feet. This poor penetration of water resulted in subsoil moisture contents near the wilting point at the beginning of the cropping season when the whole soil profile should have been recharged with water. Bulk density and noncapillary porosity measurements showed a compact layer or hardpan under the plow layer in soils where wilting was a problem. Subsoiling the previous fall resulted in an increase in water intake and an increase in yield in 1961, a year with generally adequate rainfall during the growing season.

Introduction

Physiological wilting is one of the major disorders affecting cotton grown on the medium-textured soils of the Mississippi River floodplain. Wilting of the cotton plants occurs in late summer during dry years and results in the cessation of growth and the shedding of squares and small bolls. The areas of wilted cotton, which are locally called "hot spots," may occur as small areas within a field or may occupy the entire field. Generally, wilting begins in the same part of the field. Wilting is much more severe and the wilted area much more extensive if the dry period is prolonged. Wilting occurs both on soils with coarse-textured profiles and on medium-textured soils with highly compact subsoils. In this report the relation of wilt occurrence and yield of cotton to the available moisture content of the soil and to certain soil physical properties was studied.

Materials and Methods

This study consisted of (1) a preliminary survey of soil moisture conditions in areas of cotton wilting, and (2) a detailed study of moisture extraction and cotton wilting. The preliminary survey was conducted to determine if physiological wilting occurred as a result of the depletion of available moisture from the soil. The sites sampled in the preliminary survey were in Tensas and East Carroll parishes in the Mississippi River floodplain area of Northeast Louisiana. All of the soils were classified as Commerce or Mhoon series. Since the time of this survey several soil series have been separated from the Commerce and Mhoon series in this area. Some of the soils studied may be currently classified as Dundee or other series. Eight fields in which cotton wilting occurred were sampled in August 1956 to a depth of 36 inches for available moisture analyses. Samples were taken where plants had recently wilted and in adjacent nonwilted areas. Cotton yields were estimated by harvesting and weighing mature bolls in measured plots of wilted and nonwilted cotton.

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[1] Formerly Graduate Assistant and Professor of Agronomy, respectively.

The more detailed study made in 1961 consisted of (1) the measurement of extraction patterns of available moisture throughout the growing season, (2) the measurement of the effect of subsoiling on available moisture and cotton yield, and (3) the evaluation of the effect of certain physical properties of the soils on physiological wilting of cotton. Three areas were selected for this study. Two of the areas were on Dundee loam, one at Midway Plantation and the other at Barcelona Plantation. The Dundee soil is one of the older soils of the Recent floodplain of the Mississippi River and shows evidence of profile development. Physiological wilting of cotton is common on these soils. The third area was on a Commerce fine sandy loam on the "Island" near Lake Bruin. All of the study areas were located in Tensas Parish. Cotton yields were determined by hand-picking measured plots.

A field experiment was conducted on the Dundee loam at Midway Plantation in 1961 in which the effects of subsoiling on available soil moisture content and yield of cotton were studied. Subsoiling was done the previous fall to a depth of 18 inches with a 3-inch-wide chisel which shattered the soil with a 2-inch uplift.

In both studies the soil was sampled in 6-inch increments and moisture content was determined gravimetrically. The soil was sampled to a depth of 3 feet in the preliminary study, to a depth of 5 feet at Midway and Barcelona, and to a depth of 6 feet at the "Island." Standard U.S. Weather Bureau rain gauges were installed near each field to record rainfall. Fifteen-atmosphere moisture percentage (wilting point) and 1/3-atmosphere moisture percentage (field capacity) were determined by using the pressure membrane and porous plate methods (*4*).[2] Soil texture was determined by the Soil Science Society of America proposed method (*1*) with modifications (*3*). The method of Russell and Balcerek (*5*) was used for bulk density determinations. Porosity-moisture tension curves in the low tension range were made using the tension table developed by Leamer and Shaw (*2*).

Results and Discussion

Preliminary Survey of Available Soil Moisture

The results of the survey of available soil moisture in wilt and adjacent nonwilt areas at eight locations on Mississippi River alluvial soils

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[2] Italic numbers in parentheses refer to Literature Cited, Page 22.

TABLE 1.—Available Soil Moisture and Estimated Cotton Yields on Wilted and Adjacent Nonwilted Areas of Certain Mississippi River Alluvial soils

Depth, inches	Available soil moisture storage capacity, inches		Available moisture present, inches	
	1. Mhoon loam, Tensas Parish			
	Wilted	Nonwilted	Wilted	Nonwilted
0-6	0.70	0.96	0.47	0.39
6-12	1.01	1.19	0.03	0.16
12-18	1.31	1.22	0.00	0.06
18-24	1.19	1.17	0.00	0.20
24-30	1.36	0.90	0.00	0.20
30-36	1.42	0.63	0.00	0.14
Available water-holding capacity, 0-36 inch depth	6.99	6.07		
Available water present, 12-36 inches			0.00	0.60
Lbs. seed cotton per acre			910	2,320
	2. Commerce silt loam, Tensas Parish			
	Wilted	Nonwilted	Wilted	Nonwilted
0-6	0.78	0.77	0.14	0.45
6-12	1.27	1.29	0.00	0.13
12-18	1.43	1.46	0.00	0.34
18-24	1.08	1.83	0.03	0.15
24-30	0.72	1.36	0.02	0.00
30-36	0.65	0.96	0.01	0.04
Available water-holding capacity, 0-36 inch depth	5.93	7.67		
Available water present, 12-36 inches			0.06	0.53
Lbs. seed cotton per acre			1,260	2,270
	3. Commerce silt loam, Tensas Parish			
	Wilted	Nonwilted	Wilted	Nonwilted
0-6	0.80	1.16	0.12	0.41
6-12	1.04	1.18	0.00	0.21
12-18	1.01	1.12	0.00	0.17
18-24	1.10	0.91	0.03	0.11
24-30	1.14	0.78	0.00	0.09
30-36	1.58	0.53	0.00	0.07
Available water-holding capacity, 0-36 inch depth	6.67	5.68		
Available water present, 12-36 inches			0.03	0.44
Lbs. seed cotton per acre			880	3,300

(Continued)

TABLE 1.—(Continued)

Depth, inches	Available soil moisture storage capacity, inches		Available moisture present, inches	
4. Mhoon silt loam, East Carroll Parish				
	Wilted	Nonwilted	Wilted	Nonwilted
0-6	1.09	1.42	0.19	0.73
6-12	1.20	1.59	0.03	0.29
12-18	1.07	1.46	0.02	0.33
18-24	1.05	1.26	0.00	0.22
24-30	1.08	1.55	0.00	0.24
30-36	1.24	1.45	0.00	0.23
Available water holding capacity, 0-36 inch depth	6.73	8.73		
Available water present, 12-36 inches			0.02	1.02
Lbs. seed cotton per acre			730	1,880
5. Commerce silt loam, Tensas Parish				
	Wilted	Nonwilted	Wilted	Nonwilted
0-6	0.75	0.75	0.00	0.15
6-12	0.96	1.01	0.00	0.00
12-18	1.25	0.80	0.00	0.01
18-24	1.25	1.29	0.00	0.00
24-30	1.45	1.20	0.00	0.00
30-36	1.38	0.77	0.00	0.00
Available water-holding capacity, 0-36 inch depth	7.04	5.82		
Available water present, 12-36 inches			0.00	0.01
Lbs. seed cotton per acre			840	3,080
6. Commerce loam, Tensas Parish				
	Wilted	Nonwilted	Wilted	Nonwilted
0-6	0.40	1.83	0.00	0.27
6-12	0.56	0.64	0.00	0.00
12-18	0.26	0.44	0.00	0.00
18-24	0.71	0.71	0.00	0.06
24-30	1.27	0.65	0.00	0.09
30-36	1.04	0.68	0.00	0.06
Available water-holding capacity, 0-36 inch depth	4.24	4.95		
Available water present, 12-36 inches			0.00	0.21
Lbs. seed cotton per acre			1,130	2,400

(Continued)

TABLE 1.–(Continued)

Depth, inches	Available soil moisture storage capacity, inches		Available moisture present, inches	
	7. Commerce loam, Tensas Parish			
	Wilted	Nonwilted	Wilted	Nonwilted
0-6	0.69	0.63	0.10	0.26
6-12	0.71	0.59	0.00	0.07
12-18	1.19	0.54	0.00	0.00
18-24	1.07	0.81	0.00	0.09
24-30	1.12	0.92	0.00	0.04
30-36	1.36	0.95	0.00	0.12
Available water-holding capacity, 0-36 inch depth	6.14	4.44		
Available water present, 12-36 inches			0.00	0.25
Lbs. seed cotton per acre			1,080	2,840
	8. Commerce silt loam, Tensas Parish			
	Wilted	Nonwilted	Wilted	Nonwilted
0-6	0.65	0.98	0.11	0.04
6-12	0.79	1.14	0.00	0.06
12-18	0.94	1.08	0.00	0.00
18-24	0.95	0.09	0.00	0.03
24-30	0.96	1.19	0.00	0.00
30-36	0.89	1.22	0.00	0.13
Available water-holding capacity, 0-36 inch depth	5.18	6.70		
Available water present, 12-36 inches			0.00	0.16
Lbs. seed cotton per acre			710	1,310

are shown in Table 1. In the wilt areas no available moisture was present in the upper 36 inches of soil except for a small amount in the top 6 inches as a result of a rain which fell shortly before the samples were taken. In all nonwilt areas except one, a small amount of available moisture was present in the 12-36 inch zone. Wilting of cotton was definitely associated with the depletion of available soil water.

Wilting could not be explained on the basis of the moisture storage capacity of the soils since both the wilt and nonwilt areas had similar high moisture storage capacities (Table 1). Available moisture was almost depleted in several of the nonwilt areas. There were no differences in soil texture between the wilt and nonwilt areas that could account for the differences in available soil moisture. The higher available moisture content in the nonwilt areas was very likely due to a higher moisture intake rate.

Moisture Extraction Pattern in Dundee Loam at Barcelona Plantation

The moisture extraction patterns measured during the 1961 growing season are shown in Figure 1 for the wilt area and in Figure 2 for the adjacent nonwilt area at Barcelona Plantation. Rainfall values are for total precipitation between sampling dates. Rainfall measurements were begun May 31. During exceptionally dry years, wilting has occurred on both areas. Available soil moisture to a 5-foot depth throughout the growing season for both the wilt and nonwilt areas is shown in Figure 3. In both profiles very little available moisture was present below a depth of 30 inches. The first sampling on May 3 showed subsoil moisture to be low in both the wilt and nonwilt areas, with the nonwilt area having 1.5 inches more available moisture than the wilt area.

Moisture intake by this soil was apparently very slow. During the period November through April, 33 inches of rain fell, but only 8 inches or less available moisture was present in the surface 5 feet of soil at the beginning of May. It is apparent that little of this rainfall penetrated to the subsoil, since any moisture penetrating the soil below a depth of 30 inches would have been retained in the soil because of the high moisture holding capacity of the entire profile (see Table 2).

The first part of the growing season, May and early June, was dry. The moisture lost from the soil during this period through evapotranspiration came from the surface 18 inches (Figures 1 and 2). The crop did not suffer moisture stress since the surface 2 feet of soil contained appreciable available water. Rainfall during the last part of June was above average. Water penetrated to a depth of 4 feet in the nonwilt area but did not move down as deep in the wilt area. As a result of the high rainfall in late June and early July, both profiles contained maximum moisture at the July 10 sampling. The first wilting of cotton was observed in the wilt area when it was visited on the afternoon of August 16, although it apparently occurred several days earlier. On August 16, 1.99 inches of available moisture was present in the soil profile to a depth of 5 feet. The available moisture content decreased further to 0.52 inch in the wilt area at the September 1 sampling. The plants did not recover from the initial wilting and lost all squares and small bolls. By harvest time all of the plants were dead.

Cotton grown in the nonwilt area did not wilt in 1961. Available soil moisture was higher throughout the growing season in this area than in the wilt area. The lowest available soil moisture content of the profile in the nonwilt area was 2.07 inches on September 1. Since cotton was wilted in the wilt area on August 16 when the available moisture content of the surface 5 feet was approximately 2 inches, it appears that 2 inches of available moisture fairly uniformly distributed in the surface 5 feet of soil may be the critical available moisture level for wilting in this soil.

The nonwilt area yielded 2,150 pounds of seed cotton per acre

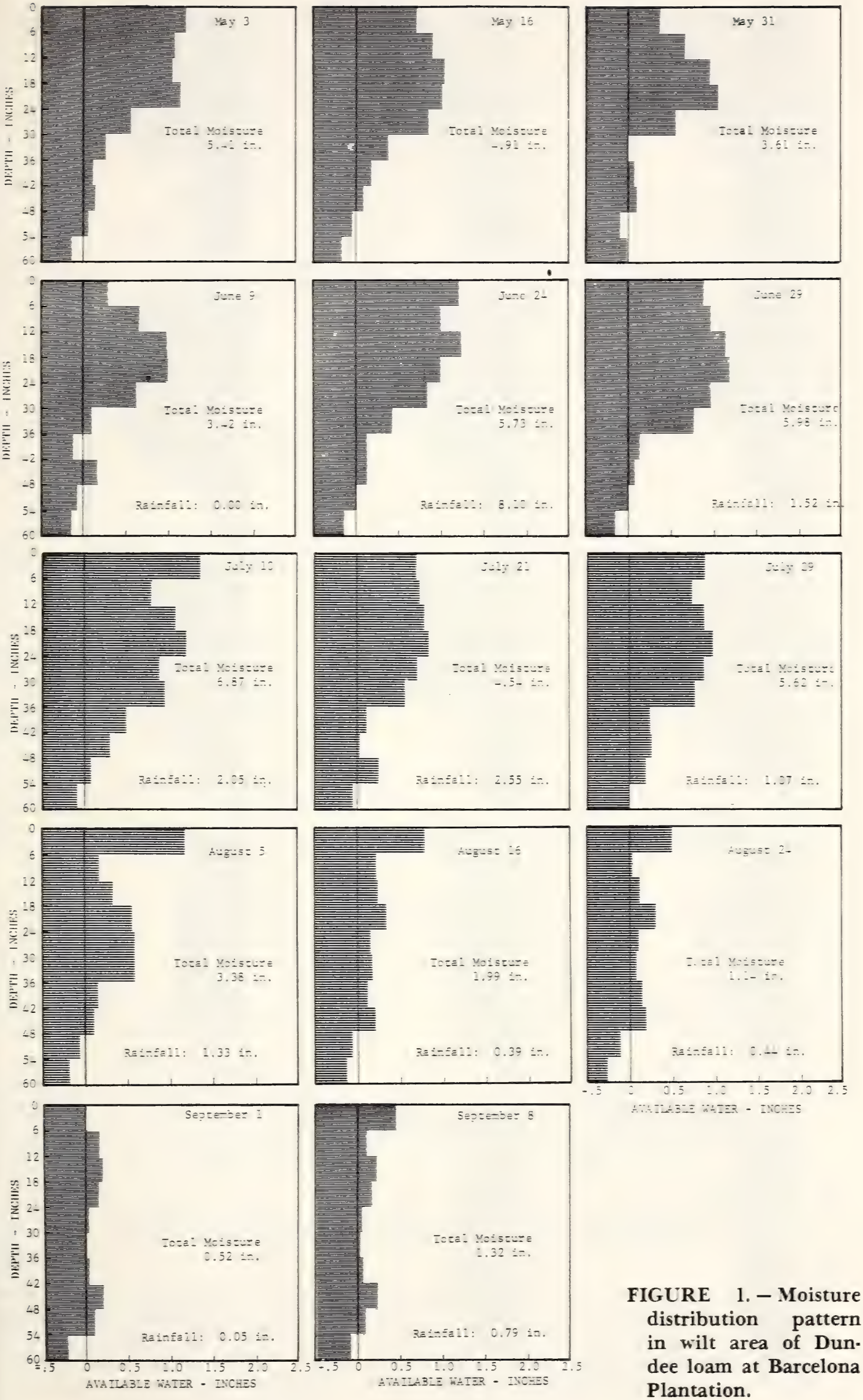

FIGURE 1. – Moisture distribution pattern in wilt area of Dundee loam at Barcelona Plantation.

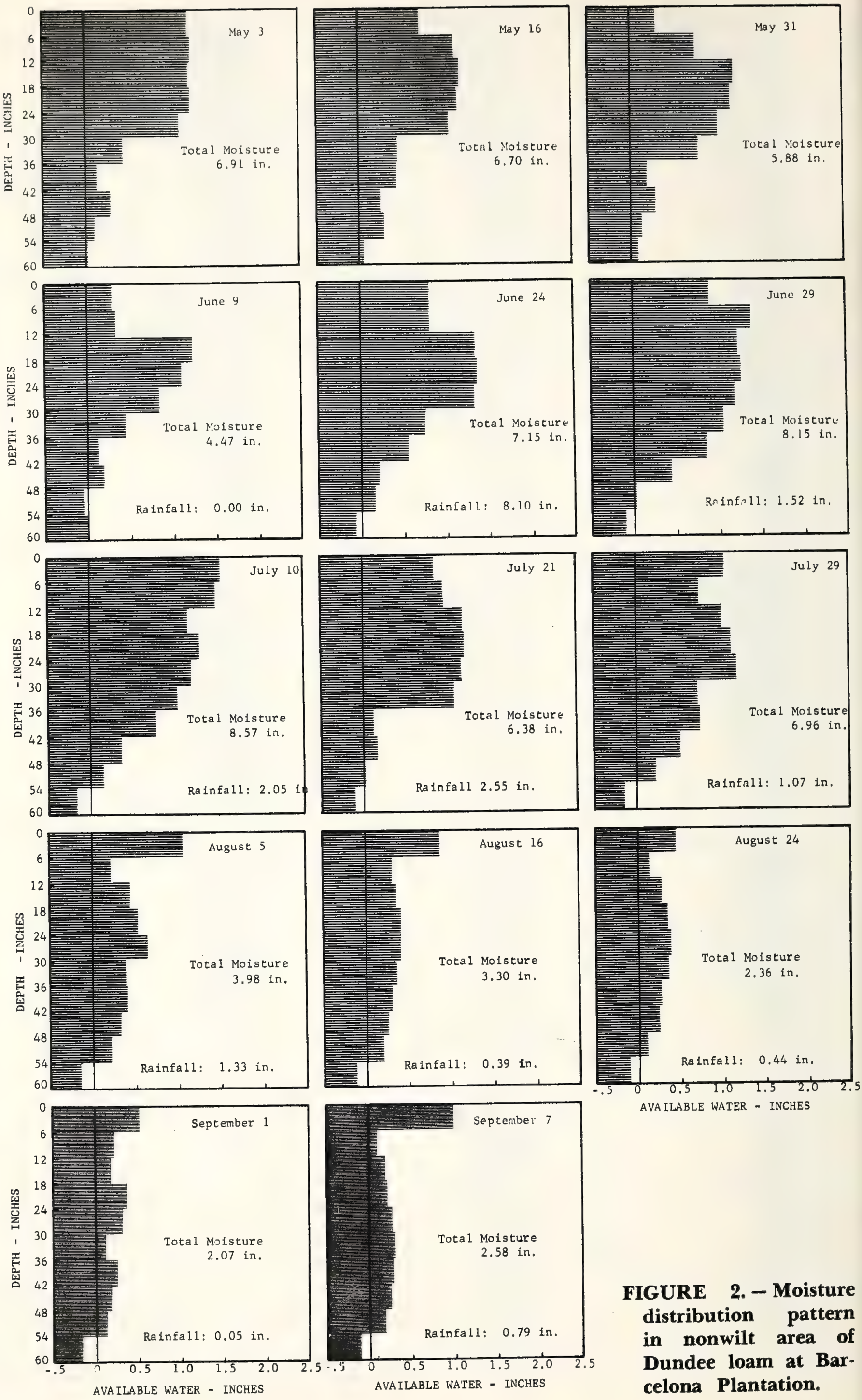

FIGURE 2. – Moisture distribution pattern in nonwilt area of Dundee loam at Barcelona Plantation.

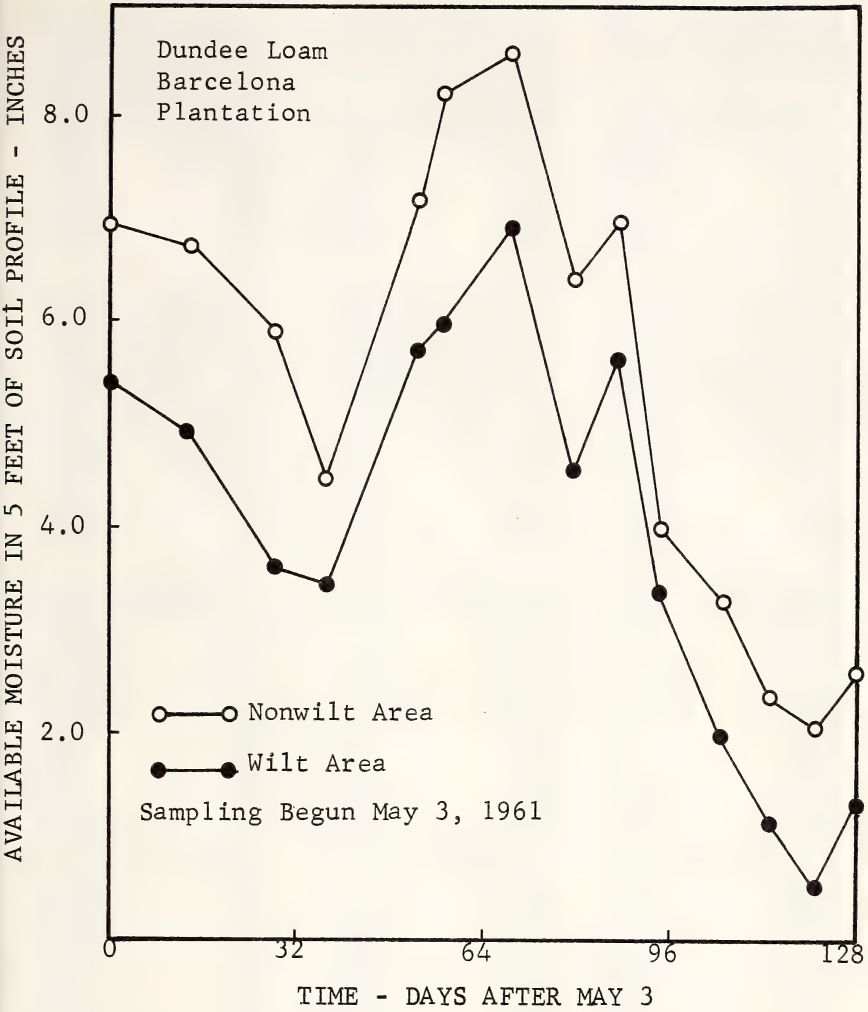

FIGURE 3.—Available moisture in wilt and nonwilt areas of Dundee loam at Barcelona Plantation.

compared with 795 pounds per acre for the wilt area. As contrasted with the wilt area, the plants remained alive in the nonwilt area and rainfall following the final picking caused second growth to occur.

Moisture Extraction Pattern in Dundee Loam at Midway Plantation

Moisture extraction patterns throughout the season in the Dundee loam at Midway Plantation are shown in Figure 4 for the subsoiled treatment and in Figure 5 for the nonsubsoiled treatment. Moisture extraction was measured in three of the subsoiled plots and in three

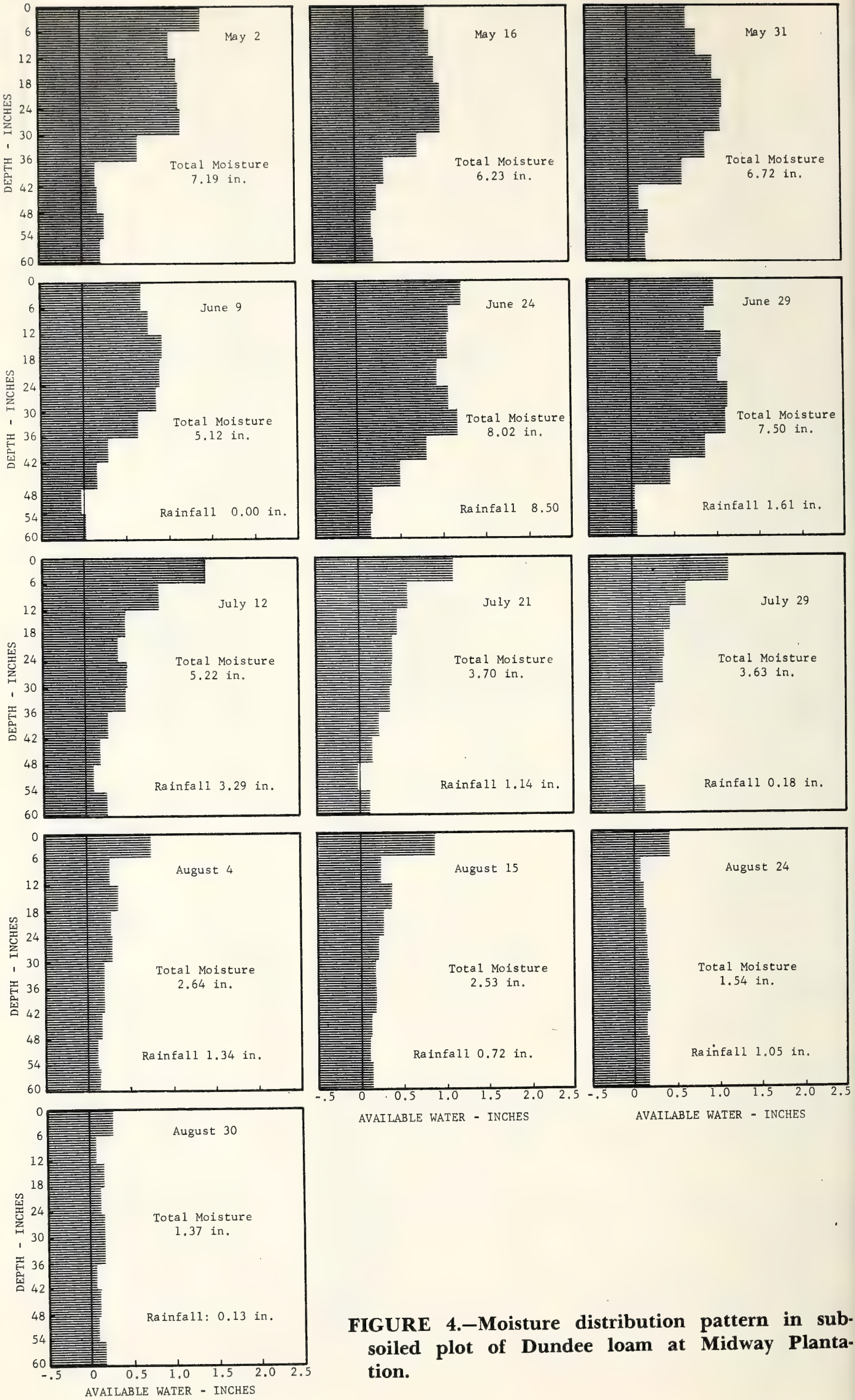

FIGURE 4.—Moisture distribution pattern in subsoiled plot of Dundee loam at Midway Plantation.

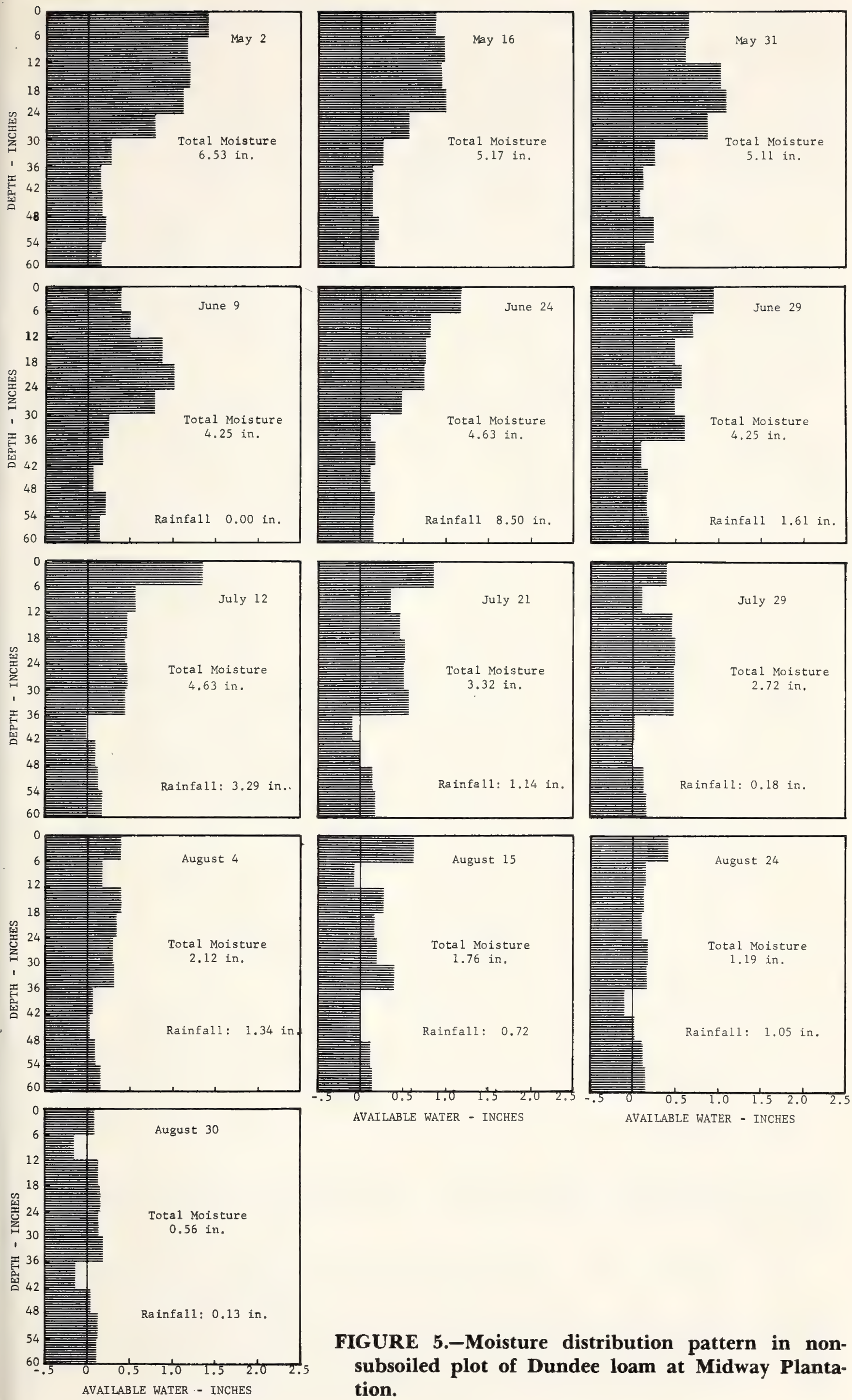

FIGURE 5.—Moisture distribution pattern in nonsubsoiled plot of Dundee loam at Midway Plantation.

of the nonsubsoiled plots. Because of the similarity of extraction patterns among the replicates of each treatment, the results for only one plot each of the subsoiled and nonsubsoiled treatments are shown. Total available moisture contents to a 5-foot depth throughout the growing season for the subsoiled and nonsubsoiled areas are shown in Figure 6. The field in which this experiment was located usually wilted in all except the wettest growing seasons.

As was the case at the Barcelona location, the subsoil was not charged with moisture at the beginning of the season. Little available water was present below 30 inches. Movement of water into this soil was very slow. Field observation during early winter showed that the soil below 1-2 feet was very dry even though the soil surface had been saturated for several days.

The pattern of moisture loss from the soil during the growing season was generally similar to that measured at Barcelona Plantation, with approximately 2 inches of water being lost from the surface 18 inches during the dry period in May and early June.

Subsoiling gave an increase (significant at the 1 per cent level of probability) in available soil moisture in the surface 5 feet of soil (Figure 6). The total available moisture in the soil was higher in the subsoiled plot than in the nonsubsoiled plot of each replication at each date of sampling. Moisture content of the subsoiled plot was higher whether computed for the upper 3 feet or the upper 5 feet of soil. The effect of subsoiling was especially evident in the moisture distribution pattern following the heavy rains in June. In the subsoiled plots water penetrated deeper than in the nonsubsoiled plots. The increase in moisture supply as a result of subsoiling occurred during a growing season in which rainfall was above normal.

Subsoiling the Dundee loam at Midway Plantation resulted in an increase in the yield of cotton. The average yield of the subsoiled plots was 2,110 pounds of seed cotton per acre and that of the nonsubsoiled plots was 1,960 pounds per acre. The increase of 250 pounds per acre was significant at the 5 per cent level of probability.

This increase in yield from subsoiling was very likely due to the increased water supply, since moisture became limiting late in the season. In a dry year yield differences due to subsoiling would probably have been greater. Saveson *et al.* (*6*) found that deep tillage of certain medium-textured Mississippi River Alluvial soils produced yield increases of 1,000 pounds of seed cotton per acre or more in extremely dry years.

Moisture Extraction Pattern in Commerce Fine Sandy Loam on the "Island"

The moisture extraction pattern of the Commerce fine sandy loam on the "Island" near Lake Bruin is presented graphically in Figure 7. Unlike the two Dundee soils, the entire profile of the Commerce soil was high in available moisture at the beginning of the growing season. During August, rainfall was not adequate to supply the needs of the

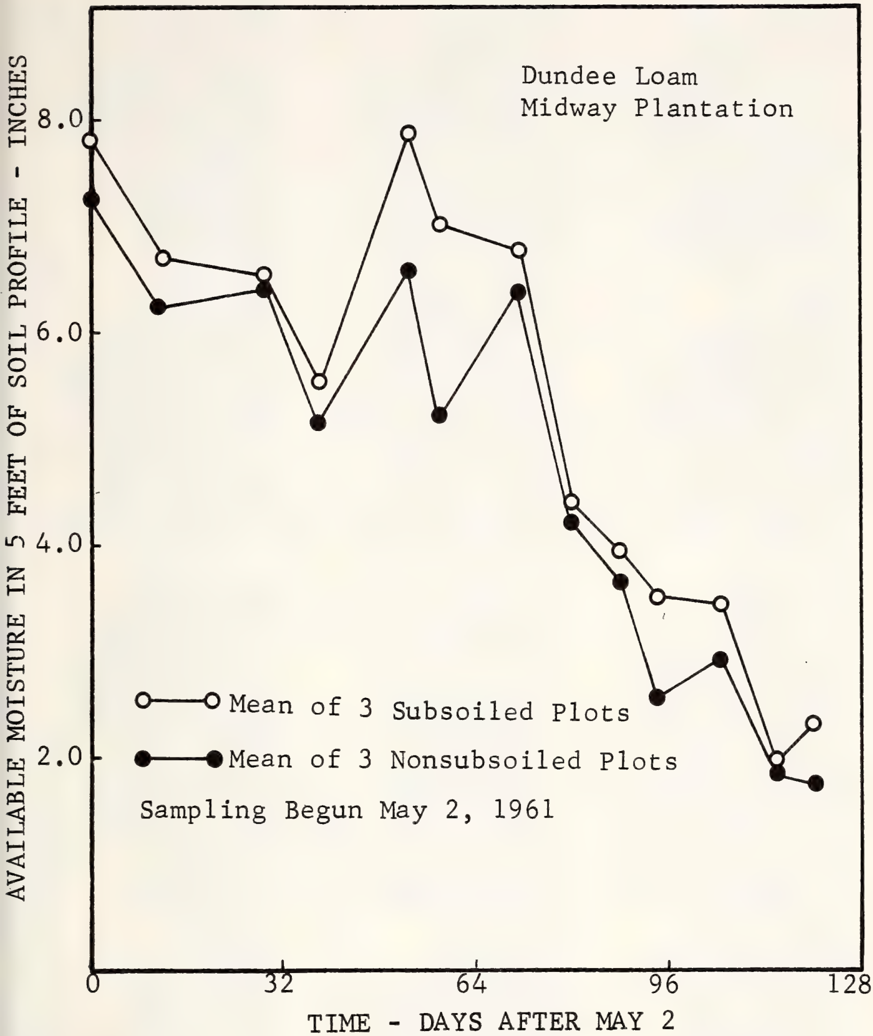

FIGURE 6.—Available moisture in subsoiled and nonsubsoiled plots of Dundee loam at Midway Plantation.

cotton crop, and a depletion of available moisture in the upper 3 feet occurred. By the last of September the upper 3-foot zone was approaching the wilting point. The subsoil was still well supplied with water, however, and the plants did not wilt. In extremely dry years, cotton has wilted at this location.

Soil Physical Properties

Measurements of physical properties of the soils are shown in Figure 8 for texture, in Tables 2, 3, and 4 for bulk density and moisture constants, and in Figures 9, 10, and 11 for pore size distribution.

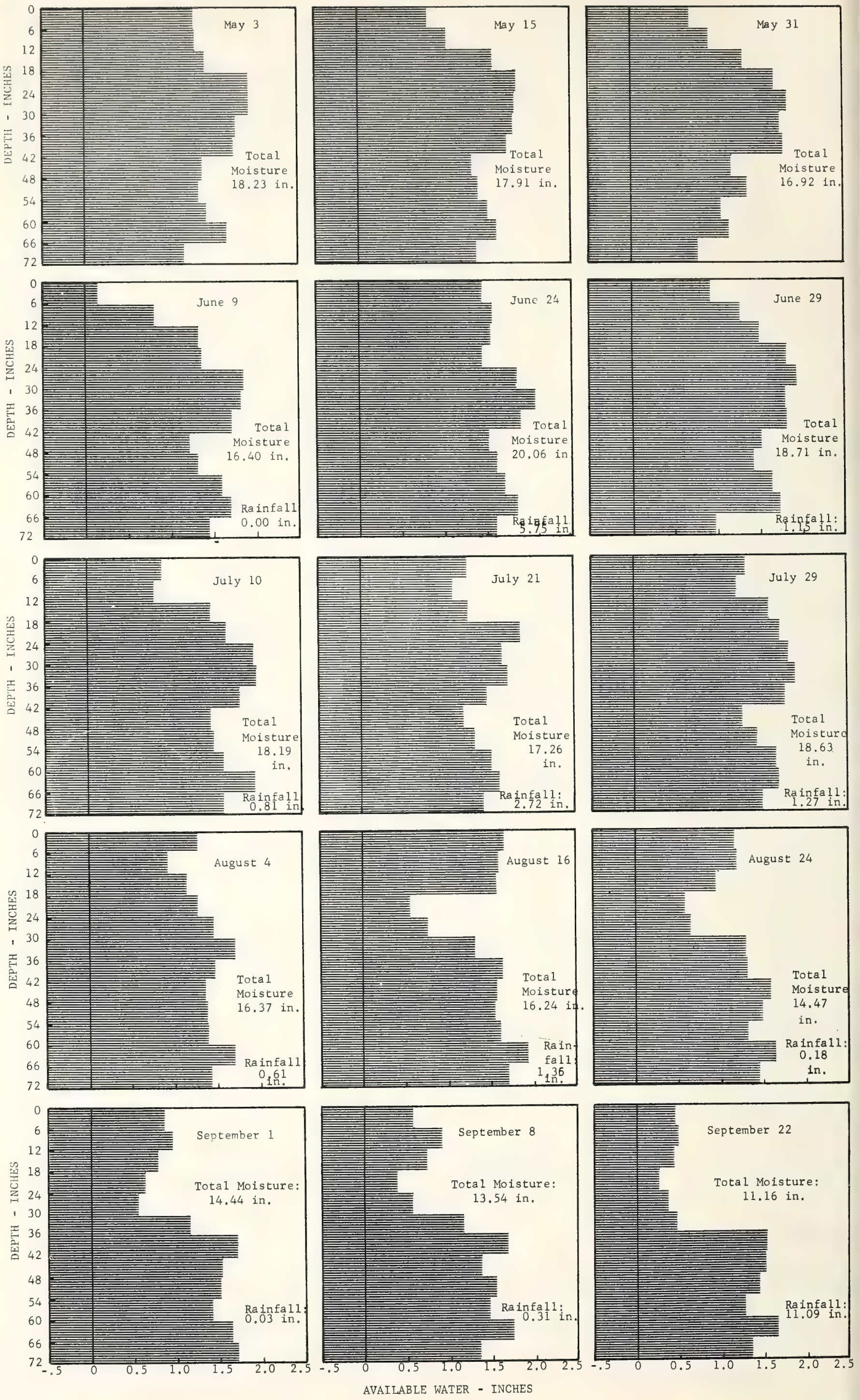

FIGURE 7.—Moisture distribution pattern in Commerce fine sandy loam at "Island."

TABLE 2.—Physical Properties of the Dundee Loam at Barcelona

Depth, inches	Bulk density, g./cc.		One-third atmosphere, %		Fifteen atmosphere, %		Available water storage capacity, inches	
	A	B	A	B	A	B	A	B
0-6	1.58	1.49	29.09	22.54	9.69	8.78	1.84	1.23
6-12	1.69	1.65	32.73	34.16	12.24	11.51	2.08	2.24
12-18	1.52	1.46	34.87	30.78	11.55	11.44	2.13	1.69
18-24	1.43	1.43	31.51	30.04	10.86	10.44	1.77	1.68
24-30	1.42	1.36	24.41	30.62	9.76	10.92	1.25	1.61
30-36	1.41	1.44	32.69	34.02	9.93	10.89	1.93	2.00
36-42	1.46	1.40	31.17	33.94	9.70	11.19	1.88	1.91
42-48	1.57	1.42	34.80	31.02	10.00	10.54	2.34	1.74
48-54	1.55	1.43	38.20	35.29	16.53	13.06	2.02	1.91
54-60	1.56	1.62	45.39	41.43	23.09	19.79	2.09	2.10
						Total	19.31	18.12

A—Nonwilt area.
B—Wilt area.

TABLE 3.—Physical Properties of the Dundee Loam at Midway

Depth, inches	Bulk density, g./cc.		Field capacity, %		Wilting point, %		Available water storage capacity, inches	
	A	B	A	B	A	B	A	B
0-6	1.54	1.54	25.02	26.36	8.80	8.83	1.79	1.65
6-12	1.61	1.58	27.47	29.43	10.41	11.01	1.57	1.70
12-18	1.48	1.50	27.29	30.16	9.24	10.00	1.60	1.80
18-24	1.44	1.44	23.76	24.05	8.66	8.32	1.30	1.38
24-30	1.47	1.48	25.43	23.85	8.82	7.78	1.47	1.43
30-36	1.43	1.44	22.17	19.58	7.41	6.40	1.27	1.16
36-42	1.43	1.43	22.72	20.38	7.35	6.99	1.32	1.17
42-48	1.43	1.47	19.72	23.02	7.11	7.72	1.08	1.37
48-54	1.45	1.46	17.28	24.58	6.62	8.29	0.93	1.42
54-60	1.39	1.47	18.54	23.52	5.92	7.02	1.06	1.46
						Total	13.39	14.54

A—Subsoiled plots.
B—Nonsubsoiled plots.

The high density in the 6- to 12-inch depth in the two Dundee soils indicates a compact horizon or hardpan. Excavation of these soils substantiated the fact that the zone directly under the plow layer was very compact. Many of the cotton roots turned horizontally after striking this compact layer. In the Commerce fine sandy loam the zone directly under the plow layer was not so compact. Bulk density was not as great and root penetration was not as restricted as in the Dundee soils.

Physiological wilting was obviously not due to differences in avail-

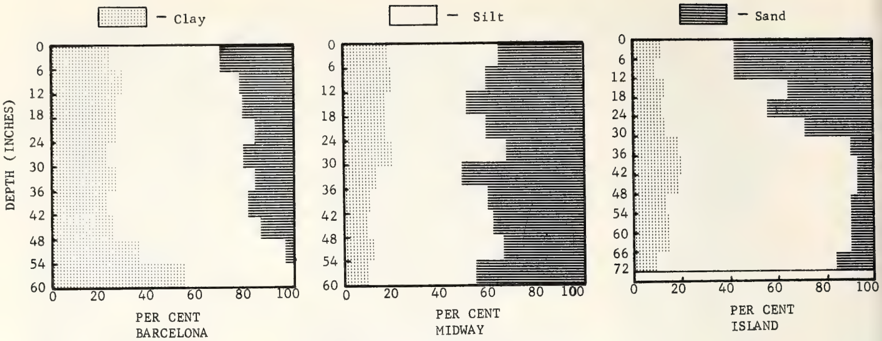

FIGURE 8.—Texture of soils.

able soil moisture storage capacity. As was the case in the preliminary survey, soils in both the wilt and nonwilt areas had high moisture storage capacities.

The high degree of compaction below the plow layer in the two Dundee soils is also indicated by the pore size distribution in the surface layer and in the pan layer, as is shown in Figures 10 and 11. Porosity was much lower in the pan layer than in the surface layers of both soils. The porosity at 60 centimeters tension, usually referred to as noncapillary porosity, was greatly below the value of 10 per cent, which is generally considered as the minimum necessary for good water and air movement and adequate root penetration. The samples from which these analyses were made were taken about a year after subsoiling and no effect of deep tillage was noted.

Pore size distribution in the Commerce soil is shown in Figure 12. Although noncapillary porosity was fairly low in both the surface

TABLE 4.—Physical Properties of the Commerce Fine Sandy Loam at the "Island"

Depth, inches	Bulk density, g./cc.	Field capacity, %	Wilting point, %	Available water storage capacity, inches
0-6	1.50	13.16	5.16	0.72
6-12	1.50	11.09	4.77	0.57
12-18	1.39	16.62	5.75	0.91
18-24	1.48	10.52	4.87	0.50
24-30	1.41	26.80	5.83	1.77
30-36	1.40	36.09	8.78	2.29
36-42	1.38	35.59	10.56	2.07
42-48	1.36	31.88	11.39	1.67
48-54	1.36	25.39	7.79	1.44
54-60	1.42	25.38	7.15	1.55
60-66	1.40	28.64	7.53	1.77
66-72	1.33	20.73	5.71	1.20
			Total	16.47

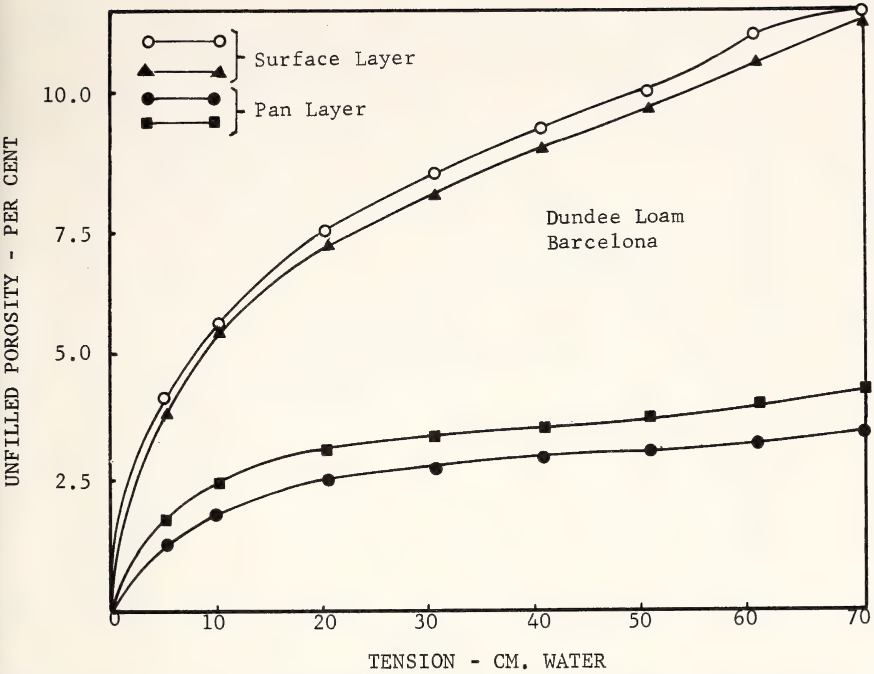

FIGURE 9.—Pore size distribution in surface and hardpan layers of Dundee loam at Barcelona Plantation.

layer and the subsurface layer, the noncapillary porosity of the subsurface layer was higher than that of the pan layers of the Dundee soils.

The physical analyses show that compaction in the two Dundee soils was great enough to limit both water penetration through the hardpan and root development in the subsoil. This was especially evident from the values of noncapillary porosity and bulk density in the hardpan layer directly under the plow layer. The slow movement of water resulted in little of the winter and early spring precipitation penetrating below a depth of 2-3 feet in the soil. During growing seasons of low rainfall the supply of stored soil moisture was not adequate for crop needs, and severe wilting resulted on these soils.

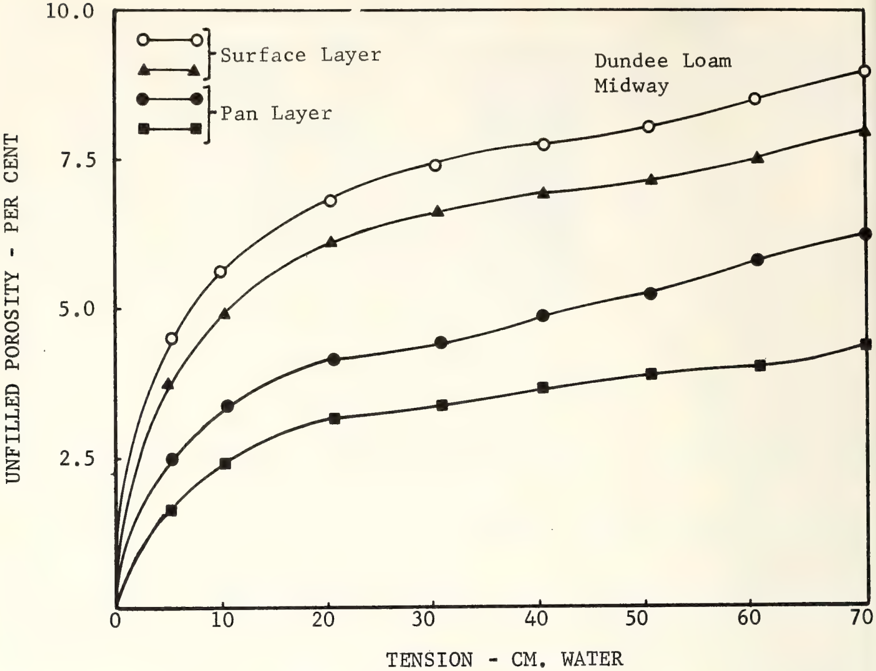

FIGURE 10.—Pore size distribution in surface and hardpan layers of Dundee loam at Midway Plantation.

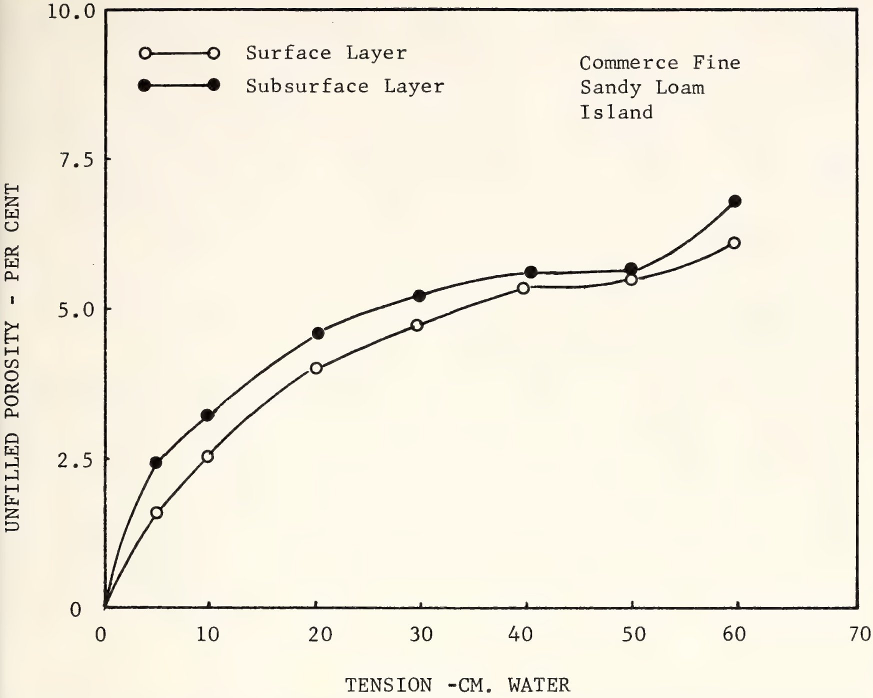

FIGURE 11.—Pore size distribution in surface and subsurface layers in Commerce fine sandy loam at "Island."

Summary and Conclusions

A study was made of physiological wilting of cotton grown on medium-textured soils of the Mississippi River floodplain. The first part of this study consisted of a preliminary survey of available soil moisture in several wilted and adjacent nonwilted locations and an estimation of the effect of wilt on cotton yields. The second part of this study consisted of (1) the measurement of moisture extraction patterns of cotton throughout the growing season in wilted and nonwilted areas, (2) measurement of the effect of subsoiling on moisture and cotton yield, and (3) the relation of various physical properties of the soils to wilting of cotton.

The preliminary study showed that physiological wilting of cotton was associated with the depletion of available soil moisture. At the time of wilting, the moisture content of subsoil was at the wilting point or below. In all but one of the adjacent nonwilted areas, available subsoil moisture was still present. Wilting was not related to soil texture or available water holding capacity of the soils.

The more detailed study of moisture extraction throughout the growing season showed that the subsoils of the two Dundee soils had not been recharged with water at the beginning of the season. Physiological wilting as a result of moisture stress occurred readily on these soils because of the early exhaustion of the limited amount of available soil moisture.

Subsoiling a Dundee loam soil gave a small increase in available soil moisture, which was significant at the 1 per cent level of probability. The increase in available moisture was reflected in a significant increase in the yield of cotton. An increase of 246 pounds of seed cotton per acre was obtained as a result of subsoiling in 1961, a year with above-average rainfall during the growing season.

The subsoil of the Commerce fine sandy loam was high in available soil moisture at the beginning of the season. Cotton grown on this soil did not suffer from a shortage of moisture.

Measurement of bulk density and porosity, as well as field observation of root penetration, showed a pronounced hardpan in the subsoil of the two Dundee soils. These hardpan layers were compact enough to seriously limit water movement and root penetration. The slow penetration of water through these compact layers could account for the low content of subsoil moisture in these soils at the beginning of the growing season and the subsequent wilting of cotton which occurred. No such hardpan was observed in the Commerce fine sandy loam.

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Effects of Magnesium and Sulphur on Growth and Chemical Composition of Clover Fourteen Coastal Plain Soils in Louisiana

R. H. Brupbacher
J. E. Sedberry, Jr.

Louisiana State University and
Agricultural and Mechanical College
Agricultural Experiment Station
Doyle Chambers, Director

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Effects of Magnesium and Sulphur On Growth and Chemical Composition of Clover on Fourteen Coastal Plain Soils in Louisiana

R. H. Brupbacher and J. E. Sedberry, Jr.[1]

Magnesium is a constituent of chlorophyll, which imparts green color to plants and is required in photosynthesis. Consequently, an adequate supply of this essential plant nutrient is necessary for optimum growth and reproduction. The formation of oil in seeds as well as the synthesis of nucleo-protein appears to be associated with the absorption and utilization of magnesium. It has been found by some scientists that the role of magnesium in these processes is also closely related to phosphates (*26*)[2].

Sulphur is also apparently essential for the formation of chlorophyll since the development of green pigment is often retarded in sulphur deficient plants (*20*). However, sulphur is not a constituent of chlorophyll.

Nutritional problems involving magnesium and sulphur, and possibly some micronutrients, develop with the use of higher-analysis fertilizers, which are generally free of the impurities ordinarily contained in lower analysis materials (*28*).

Frequently on the upland soils of Louisiana, low levels of magnesium are associated with low levels of calcium. Soil test summary data (*19*) indicate that the Coastal Plain Soils of Louisiana often contain low amounts of available magnesium. Vernon, Winn, and Union parishes and the hill sections of Caddo and Bossier parishes are the areas where this element is the lowest. Seventy-five per cent of the samples tested low in these areas. A deficiency of calcium and magnesium usually results in a low degree of base saturation and the development of a high degree of acidity (*22*). For this reason, consideration should be given to the pH, the degree of base saturation, and the contents of available magnesium and calcium in order to determine the need of a soil for lime.

Greenhouse studies were conducted on 14 soils of the Coastal Plain areas of Louisiana. The objectives were: (a) to determine the level of available soil magnesium at which response to added magnesium could be expected, and (b) to investigate the influence that fertilizers containing sulphur might have on the response to added magnesium.

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[1] Assistant Professor of Agronomy and Professor of Agronomy, Louisiana State University, respectively.

[2] Figures in parentheses refer to literature cited on pages 18 and 19.

Review of Literature

In a review of literature of magnesium research, Brown (*4*) pointed out that the majority of the magnesium research work has been in the field of horticultural crops. Potatoes, beans, tomatoes, and citrus have been investigated most frequently. In the field of forage and grain crops, soybeans, alfalfa, wheat and corn have been tested more frequently with only occasional data reported for grasses. Applications of magnesium seldom result in marked increases in yield of forage crops and much of the study of magnesium has dealt with factors other than yield response.

Both plant and soil analysis have been used to evaluate the availability of soil magnesium. Magnesium contents of leaves have been used to determine the availability of soil magnesium (*10, 12, 15, 18*). Bear and Prince (*3*) concluded that Coastal Plain soils are most likely to be deficient in magnesium. This is because of the low amount of magnesium originally present in the soil and the depressive effect that potassium has on magnesium. Results of work in Alabama showed that some coarse-textured Coastal Plain soils became magnesium deficient following intensive cropping in the greenhouse (*23*). Crotolaria and peanuts responded most while corn responded least to magnesium fertilization. Cotton and crimson clover gave considerable response and turnips, relatively little. Although crop yield data showed a response of certain crops to magnesium on some soils, a correlation between crop response and magnesium content of the soil indicated that crop response could not be predicted from the magnesium content of the soil. Magnesium deficiencies in the Southeast have also been observed on highly fertilized soils with vegetables, tobacco, and citrus (*6, 7, 16*). Prince, Zimmerman, and Bear (*21*) concluded that if magnesium constitutes less than 6 per cent of the exchange cations in the soil, crops growing on that soil are likely to respond markedly to application of soluble magnesium. The ideal amount of magnesium is believed to be approximately 10 per cent of the total exchange capacity of the soil. Response to magnesium additions is governed in part by the ratio of magnesium to the other cations on the exchange complex. The ideal ratios are 65 per cent calcium, 10 per cent magnesium, 5 per cent potassium and 20 per cent allotted to hydrogen.

Lancaster (*15*) studied the magnesium status of blackland soils of Mississippi. He found that an excellent relationship existed between percentage saturation of the soil exchange complex with magnesium and the magnesium content of leaves of cotton grown on these soils. Therefore, either chemical analysis of selective leaf samples or the soil may be employed to predict the need of magnesium for profitable cotton production. He predicted that response to magnesium would not be expected if magnesium constituted more than 6.4 per cent of the cation exchange complex of the soil and if the magnesium content of the cotton leaves was more than 25 me. per 100 grams.

Graham, Powell, and Carter (*11*) studied the response of soybeans grown on 15 Missouri soils under intensive greenhouse cropping conditions. The highest correlation between the amount of magnesium shown by soil test and per cent increases in yield was obtained when the soil was extracted with 0.05N HCl. The amount of magnesium extracted was more highly correlated with the percentage of increase in yield from added magnesium than were the calcium-magnesium ratios or the percentage of magnesium saturation. The authors concluded, however, that soils in which magnesium represented less than 10 per cent of total cation exchange capacity showed yield response to added magnesium.

Adams and Henderson (*1*) studied the availability of soil magnesium on seven major soil types of Alabama by growing Sudan grass and Ladino clover in the greenhouse. They showed that a yield response to magnesium was obtained on soils that had less than 4 per cent of the cation exchange capacity represented by magnesium. Per cent magnesium saturation proved to be a better indicator of available magnesium than did exchangeable magnesium or the ratio of exchangeable magnesium to potassium.

It appears to be established that magnesium in plant nutrition acts as a carrier of phosphorus. The literature dealing with magnesium-phosphorus relationships in plant nutrition has been reviewed by Truog, Goates, Gerloff, and Berger (*26*). The results of most of the past experiments reveal a positive correlation between magnesium and phosphorus. Truog and his associates studied the relationship of the supply of magnesium to phosphorus content of pea seeds by field and culture test in which the supplies of available magnesium and phosphorus were varied. Increases in phosphorus content occurred with increasing amounts of available magnesium. Increasing supplies of available magnesium increased the phosphorus content of the peas much more than did increasing supplies of available phosphorus. It was concluded that attention should be given to supplies of available magnesium in soils in order that the phosphorus present in the soil might be used more efficiently. Tucker and Smith (*27*) found a definite positive correlation between phosphorus and magnesium in red clover plant material. Correlation was high on soils which were relatively low in degree of magnesium saturation. Bartholomew (*2*) studied the availability of phosphate fertilizers and noted that plants took up increased amounts of phosphorus when magnesium sulphate was added.

Jacob (*12*) recently reviewed research on fertilizer experiments with magnesium. He reported on pot experiments with oats in which the effect of the magnesium ion and the sulphate ion was studied. It was reported that the effect of the magnesium ion was especially favorable if it was applied in combination with the sulphate ion.

Jeane (*13*) studied the relationships of sulphur, magnesium and phosphorus in the nutrition of white clover. He found that treatments of dolomitic lime and sulphur gave significantly higher yields of clover than those obtained from dolomitic limestone without sulphur when superphosphate and treble superphosphate were used. The relationships between the absorption of sulphur, phosphorus, and magnesium as shown by the correlation coefficients indicate that added sulphur enhances the absorption of native magnesium in the soil and that magnesium enhances the absorption of phosphorus.

Conrad, Hall, and Chaugule (*8*) conducted experiments in which they applied 100 pounds per acre of elemental sulphur, 250 pounds per acre of treble superphosphate, and sulphur plus phosphate at the same rate as singly. Though some increases were noted from the treble superphosphate alone, they were small in comparison with the sulphur responses. They may have resulted in part from the small quantities of sulphur present in the phosphate fertilizer. Applications of sulphur resulted the first year in a three- to four-fold increase in yield of dry matter obtained for legumes, principally for clover. In the years following, yields of nonlegumes following the sulphured legumes were increased up to double the yields of the unfertilized plots.

Recent experimental evidence indicates that the presence of the sulphate ion may have a significant effect on phosphorus uptake by plants (*24*). It was found that when ammonium sulphate is mixed with a water soluble phosphatic fertilizer and applied in a band, there is a great proliferation of roots in the band and a greatly increased uptake of phosphorus by the plant. The effect does not occur when the nitrogen is in the nitrate form, nor does it occur if the sulphate ion is not present.

In field experiments conducted in the South, sulphur-free fertilizers applied alone and with supplements of sulphur as gypsum were compared. Supplementary sulphur increased yields in 15 of 22 experiments with cotton, forage crops, and tobacco (*14*). A positive phosphorus and sulphur interaction was indicated. Sulphur had no effect on yield of clover at the minimum phosphorus level. At adequate phosphorus levels and higher levels of sulphur, yields of dry matter were about five times the production of clover in the absence of sulphur.

Experimental

Acidic soils considered to be relatively low in dilute acid extractable or exchangeable magnesium were selected for greenhouse studies. Soils from the Coastal Plain areas of Louisiana used in this investigation included the following series: Bowie, Ruston, Shubuta, Lakeland, Eustis, Luverne, Orangeburg, and Kirvin. Cation exchange capacity varied from 2.7 to 6.4 me. per 100 gms. of soil. Initially the reaction of the soils included a pH range from 5.2 to 6.0. For the purpose of identification and convenience in reporting, each soil is assigned a number from 1 through 14. Soil identification and specific chemical properties are listed in Table 1. Bulk samples of surface soil were collected. The soil material was screened and 16 pounds of dry soil was placed in two-gallon pots.

TABLE 1.—Chemical properties of selected Coastal Plain soils

Soil		Location	Extractable					Cation	Exch.
No.	Soil Type	(Parish)	P	Mg	Ca	K	pH	Exch. Cap.	Mg
			– – Parts per million – –					me./100gm.	%
1	Bowie fsl*	Vernon	9	25	216	39	5.2	4.40	4.7
2	Ruston sl	Washington	5	21	108	26	5.3	2.93	5.9
3	Ruston lfs	Claiborne	9	23	194	39	5.8	2.72	6.9
4	Shubuta fsl	Claiborne	9	25	130	39	5.5	3.20	6.4
5	Lakeland ls	Claiborne	43	30	216	30	5.9	3.39	7.2
6	Ruston sl	Ouachita	9	52	475	48	6.0	6.37	6.7
7	Eustis lfs	Bienville	53	27	216	39	5.8	2.96	7.5
8	Ruston sl	Vernon	109	33	432	30	5.7	4.00	6.7
9	Luverne fsl	St. Helena	20	43	259	48	5.9	4.53	7.8
10	Ruston fsl	Red River	36	28	136	36	5.5	2.76	8.3
11	Lakeland fs	Bienville	56	21	181	14	5.6	2.93	5.9
12	Ruston sl	Winn	20	25	227	27	5.7	4.04	5.1
13	Orangeburg sl	Ouachita	80	60	346	86	6.0	4.65	10.6
14	Kirvin fsl	Bienville	31	55	272	82	5.3	4.73	9.9

*fsl, fine sandy loam; sl, sandy loam; lfs, loamy fine sand; ls, loamy sand; fs fine sand.

Studies were conducted to determine the effects of different sources of phosphorus, magnesium, and liming materials on the growth of Ladino clover. Ground oyster shells and dolomitic limestone were used with two sources of phosphorus with and without the application of soluble magnesium. Soluble magnesium at the rate of 32 pounds of MgO per acre was applied as sulphate of potash-magnesia (Sul-Po-Mag) containing 18.5 per cent MgO and 21.5 per cent K_2O. Liming materials were applied in an amount sufficient to raise the pH of the soil to approximately 6.5. All soils received the equivalent of 24 pounds of nitrogen as amonium nitrate, 96 pounds of P_2O_5 (42 pounds of P) and 96 pounds of K_2O (80 pounds of K) per acre. The sources of phosphorus were ordinary superphosphate, 20 per cent P_2O_5, and concentrated superphosphate, 48 per cent P_2O_5. Potassium chloride, 60 per cent K_2O, and sulphate of potash-magnesia were used as the sources of potassium.

Studies were also conducted to determine the effects of sources of liming materials, magnesium and sulphur on the growth of Ladino clover and Tensas red clover. Magnesium nitrate, calcium sulphate, and sulphate of potash-magnesia (Sul-Po-Mag) were applied with ground oyster shells. A treatment was also included which did not contain magnesium or sulphur, and this served as the control. Dolomitic limestone was used with and without calcium sulphate. Ground oyster shells and dolomitic limestone were applied in an amount sufficient to raise the pH of the soil to approximately 6.8. All soils received the equivalent of 36 pounds of nitrogen, 144 pounds of P_2O_5, (63 pounds of P) and 144 pounds of K_2O (120 pounds of K) per acre. Concentrated superphosphate containing 48 per cent P_2O_5 was the source of phosphorus. Soluble magnesium, at the rate of 48 pounds of MgO per acre, was applied as sulphate of potash-magnesia and magnesium nitrate. Sulphur was applied at a rate of 60 pounds per acre as calcium sulphate and sulphate of potash-magnesia. The sources of nitrogen were ammonium nitrate and magnesium nitrate. Potassium chloride and sulphate of potash-magnesia served as sources of potassium.

The soils under the different treatments were planted to clover. The clover was clipped three or four times, depending upon its growth. The plant material was dried at 70° C. and weighed. Total weights in grams per pot are presented in Tables 2 and 5. Dry plant material was analyzed for magnesium, phosphorus, and sulphur by the methods described by Toth, Prince, Wallace, and Mikkelsen (*25*). Soil magnesium, calcium, and potassium were extracted with 0.1N hydrochloric acid. The soil-solution ratio was 1:20 and extracting time was 15 minutes. The concentration of calcium and potassium were determined with a Perkin-Elmer flame photometer, using lithium as an internal standard. Magnesium was determined by the Clayton yellow colorimetric method (*17*). Phosphorus was extracted with 0.1N hydrochloric acid solution containing 0.03N ammonium fluoride solution at a 1:20 soil to solution ratio as described by Byrnside and Sturgis (*5*). Color intensity was measured with a Bausch and Lomb spectrophotometer. Soil reaction was determined with a Leeds and Northrup glass electrode pH meter using a 1:1 soil-water suspension that had been allowed to stand 12 hours. Total exchange capacity, reported in milliequivalents per 100 grams of dry soil, was determined by agitating and leaching the soil with 0.5N barium acetate adjusted to pH 7.5 as recorded by Driskell (*9*).

Discussion of Results

Effects of Nutrient Sources on Yield and Nutrient Uptake

The results of greenhouse experiments on effects of different sources of phosphorus and magnesium on the yield of Ladino clover grown on five Coastal Plain soils in Louisiana are reported in Table 2. Soils included in this investigation are Bowie fine sandy loam, Ruston sandy loam, Ruston loamy fine sand, Shubuta fine sandy loam, and Lakeland loamy sand. In general, the data indicate that higher clover yields were obtained from the addition of superphosphate than from concentrated superphosphate when soluble magnesium was not included in the treatment. Significant increases in yield of clover were obtained when soluble magnesium was used with concentrated superphosphate. However, soluble magnesium did not always increase the yield of clover when superphosphate was the source of phosphorus. When ground oyster shells were used and superphosphate served as the source of phosphorus, soluble magnesium failed to increase the yield of clover grown on Ruston sandy loam and Ruston loamy fine sand. On these two soils, the sulphate as calcium sulphate in the ordinary superphosphate increased yield

TABLE 2.—Effects of liming materials, sources of phosphorus, and magnesium on yield of Ladino clover grown on five Coastal Plain soils

Treatments*	Bowie fsl (1)	Ruston sl (2)	Ruston lfs (3)	Shubuta fsl (4)	Lakeland ls (5)	Average five soils
	– – – – – – – – Yield, grams per pot – – – – – –					
Oyster shells						
Superphosphate	23.4	19.5	19.5	31.8	25.5	23.9
Superphosphate + Mg**	26.8	17.2	19.4	32.3	29.4	25.0
Conc. Superphosphate	20.8	14.0	13.8	29.7	18.4	19.3
Conc. Superphosphate + Mg	28.8	16.8	16.8	32.6	28.2	24.6
Dolomitic Limestone						
Superphosphate	20.9	16.7	14.2	33.1	26.0	22.2
Superphosphate + Mg	22.0	14.2	19.0	30.1	27.3	22.5
Conc. Superphosphate	19.7	15.3	16.8	22.0	19.5	18.7
Conc. Superphosphate + Mg	23.9	17.3	21.5	28.8	26.2	23.5
L.S.D. @ 5%	1.1	1.0	1.5	1.1	1.2	
L.S.D. @ 1%	1.5	1.3	2.0	1.4	1.6	

*All treatments received the equivalent of 24 pounds of nitrogen, 96 pounds of P_2O_5, and 96 pounds of K_2O per acre.

**Soluble magnesium applied as sulphate of potash-magnesia (Sul-Po-Mag) containing 18.5 per cent MgO and 21.5 per cent K_2O.

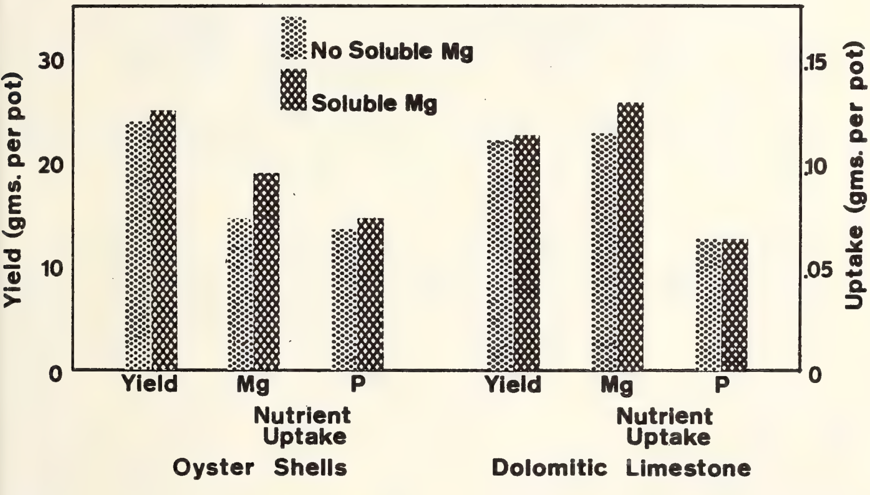

FIGURE 1.—Effect of soluble magnesium as sulphate of potash-magnesia on yield of clover and plant nutrient uptake when ordinary superphosphate served as the source of phosphorus (Five soils listed in Table 2).

of clover more than added magnesium and sulphate supplied by sulphate of potash magnesia.

Total magnesium and phosphorus uptake by clover are presented in Tables 3 and 4 and Figures 1 and 2. In this discussion, plant nutrient uptake data is used as a measure of magnesium and phosphorus availability. The effect of ordinary superphosphate with soluble magnesium on yield of clover and uptake of magnesium and phosphorus, as an average of five Coastal Plain soils, is presented in Figure 1. Yield of clover was increased slightly by the addition of a soluble source of magnesium when ground oyster shells were used as the liming material. This increase amounted to 4.9 per cent. A corresponding increase in the uptake of phosphorus was observed. When dolomitic limestone was used as the liming material, the addition of a soluble source of

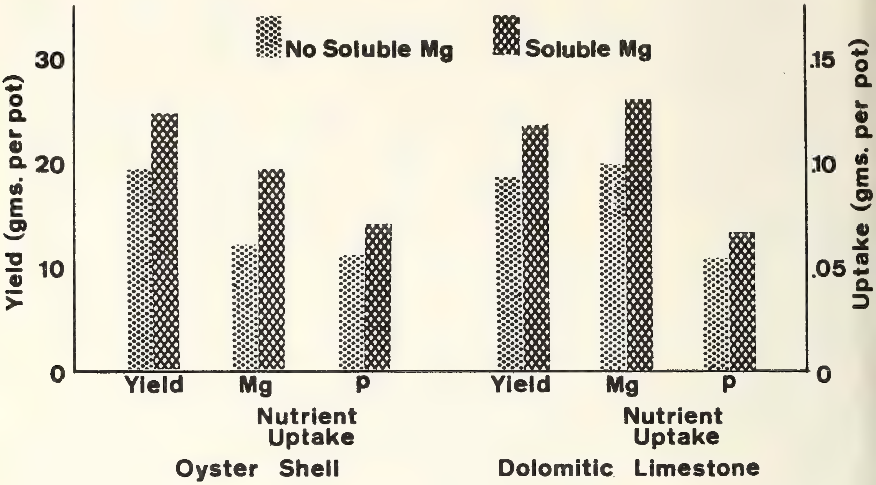

FIGURE 2.—Effect of soluble magnesium as sulphate of potash-magnesia on yield of clover and plant nutrient uptake when concentrated superphosphate served as the source of phosphorus (Five soils listed in Table 2).

TABLE 3.—Effects of liming materials, sources of phosphorus, and magnesium on magnesium uptake by Ladino clover grown on five Coastal Plain soils

Treatments*	Bowie fsl (1)	Ruston sl (2)	Ruston lfs (3)	Shubuta fsl (4)	Lakeland ls (5)	Average five soils
	– – – Magnesium uptake, mg. per pot – – –					
Oyster shells						
Superphosphate	96	44	65	89	73	73
Superphosphate + Mg**	128	51	78	117	95	94
Conc. Superphosphate	74	34	50	86	57	60
Conc. Superphosphate + Mg	125	51	74	117	95	92
Dolomitic Limestone						
Superphosphate	129	70	93	154	125	114
Superphosphate + Mg	144	64	132	160	139	128
Conc. Superphosphate	107	77	119	99	87	98
Conc. Superphosphate + Mg	143	82	126	157	144	130

*All treatments received the equivalent of 24 pounds of nitrogen, 96 pounds of P_2O_5, and 96 pounds of K_2O per acre.

**Soluble magnesium applied as sulphate of potash-magnesia (Sul-Po-Mag) containing 18.5 per cent MgO and 21.5 per cent K_2O.

magnesium had no significant effect on yield. Likewise, the uptake of phosphorus was not influenced by the inclusion of soluble magnesium in the fertilizer treatment.

Yield and nutrient uptake of clover grown on five Coastal Plain soils that received concentrated superphosphate are summarized in Figure 2. When a soluble source of magnesium was applied, a yield increase of 26.8 per cent was recorded when both oyster shells and dolomitic limestone were used. A corresponding increase of 24.8 per cent in the uptake of phosphorus was obtained. Since the source of soluble magnesium employed in this investigation was sulphate of potash-magnesia, response to additions of this material was thought to be due to magnesium or sulphur or the combined effect of both magnesium and sulphur on growth and chemical composition of clover.

By comparing data included in both Figures 1 and 2, it can be seen that 21.4 per cent higher clover yields were obtained when ordinary superphosphate served as the source of phosphorus and soluble magnesium was not used. Correspondingly higher magnesium and phosphorus uptakes were also obtained. This indicates that sulphates in ordinary superphosphate increased the availability of native soil magnesium and increased the uptake of phosphorus. Ordinary superphosphate, when used with dolomitic limestone, increased the availability of magnesium. Recent experimental evidence indicates that the presence of the sulphate ion may have a significant effect on phosphorus uptake by plants (*24*). Jeane (*13*) reported that the application of sulphur increases the availability of native soil magnesium.

TABLE 4.—Effects of liming materials, sources of phosphorus, and magnesium on phosphorus uptake by Ladino clover grown on five Coastal Plain soils

Treatments*	Bowie fsl (1)	Ruston sl (2)	Ruston lfs (3)	Shubuta fsl (4)	Lakeland ls (5)	Average five soils
	---- Phosphorous uptake, mg. per pot ----					
Oyster shells						
Superphosphate	62	57	48	87	87	68
Superphosphate + Mg**	69	50	51	96	100	73
Conc. Superphosphate	46	40	40	83	68	55
Conc. Superphosphate + Mg	66	48	45	89	102	70
Dolomitic Limestone						
Superphosphate	54	48	39	90	86	63
Superphosphate + Mg	58	42	47	71	95	63
Conc. Superphosphate	49	47	46	53	74	54
Conc. Superphosphate + Mg	60	51	54	72	94	66

*All treatments received the equivalent of 24 pounds of nitrogen, 96 pounds of P_2O_5, and 96 pounds of K_2O per acre.

**Soluble magnesium applied as sulphate of potash-magnesia (Sul-Po-Mag) containing 18.5 per cent MgO and 21.5 per cent K_2O.

TABLE 5.—Effects of liming materials, magnesium and sulphur on yields of Ladino and Tensas red clover grown on nine Coastal Plain soils

Treatments*	Ruston** sl (6)	Eustis lfs (7)	Ruston sl (8)	Luverne fsl (9)	Ruston fsl (10)	Lakeland fs (11)	Ruston sl (12)	Orange-burg sl (13)	Kirvin fsl (14)
	Yield, grams per pot								
Oyster shells	21.3	33.3	24.3	23.5	20.4	20.2	19.1	23.0	29.1
Oyster shells + Mg and S***	24.5	39.8	33.9	37.7	38.8	51.4	41.3	45.1	51.9
Oyster shells + $MgNO_3$	23.3	35.5	24.3	24.2	20.7	21.3	18.8	21.9	29.5
Oyster shells + $CaSO_3$	23.4	35.6	31.0	35.8	37.3	44.9	38.6	45.4	51.4
Dolomitic Limestone	22.5	37.1	27.0	23.9	18.3	18.9	17.1	18.5	25.9
Dolomitic Limestone + $CaSO_4$	25.4	39.2	33.4	35.3	37.7	53.2	38.8	41.4	48.3
L.S.D. @ 5%	1.0	1.3	1.4	1.3	1.4	1.6	1.2	1.6	1.7
L.S.D. @ 1%	1.3	1.8	1.8	1.8	1.9	2.1	1.6	2.2	2.3

*All treatments received the equivalent of 36 pounds of nitrogen, 144 pounds of P_2O_5 and 144 pounds of K_2O per acre.

**Ladino clover grown on soil No. 6, red clover grown on soils Nos. 7 through 14.

***Magnesium and sulphur applied as sulphate of potash-magnesia (Sul-Po-Mag) containing 18.5 per cent MgO, 21.5 per cent K_2O and 22.7 per cent S.

TABLE 6.—Effects of liming materials, magnesium and sulphur on magnesium uptake by Ladino and Tensas red clover grown on nine Coastal Plain soils

Treatments*	Ruston** sl (6)	Eustis lfs (7)	Ruston sl (8)	Luverne fsl (9)	Ruston fsl (10)	Lakeland fs (11)	Ruston sl (12)	Orange-burg sl (13)	Kirvin fsl (14)
	Magnesium uptake, mg. per pot								
Oyster shells	91	72	93	89	66	51	71	104	110
Oyster shells + Mg and S***	118	133	156	164	142	147	185	240	235
Oyster shells + $MgNO_3$	114	131	113	114	84	74	81	118	121
Oyster shells + $CaSO_4$	110	80	116	126	96	84	126	185	244
Dolomitic Limestone	142	201	154	142	68	94	97	131	117
Dolomitic Limestone + $CaSO_4$	174	220	187	221	220	301	268	356	289

*All treatments received the equivalent of 36 pounds of nitrogen, 144 pounds of P_2O_5, and 144 pounds of K_2O per acre.

**Ladino clover grown on soil No. 6, red clover grown on soils Nos. 7 through 14.

***Magnesium and sulphur applied as sulphate of potash-magnesia (Sul-Po-Mag) containing 18.5 per cent MgO, 21.5 per cent K_2O

Effects of Magnesium and Sulphur on Yield and Nutrient Uptake

Since apparent responses to added magnesium appeared to be associated with sources of magnesium and sources of phosphorus containing sulphur, an experiment was designed to determine effects of magnesium and sulphur, applied separately and in combination, on yield and nutrient uptake by clover. Treatments used and yield data are presented in Table 5. On three soils, Ruston sandy loam, Eustis loamy fine sand, and Ruston sandy loam (soils 6, 7 and 8), higher clover yields resulted when dolomitic limestone was used than when oyster shells were employed. Clover showed favorable responses to magnesium on these soils. Yield increases were not obtained from the application of dolomitic limestone on Luverne fine sandy loam, Ruston fine sandy loam, Lakeland fine sand, Ruston sandy loam, Orangeburg sandy loam, and Kirvin fine sandy loam (soils 9, 10, 11, 12, 13, 14). Soil analysis data presented in Table 1 indicate that the magnesium contents of Orangeburg and Kirvin soils were relatively high; consequently, a response to supplementary magnesium was not expected. On Luverne fine sandy loam, Ruston fine sandy loam, Lakeland fine sand, and Ruston sandy loam (soils 9, 10, 11, 12), the magnesium levels were relatively low and yield responses to added magnesium were expected, but these responses were not obtained. When calcium sulphate was used with dolomitic limestone, significant increases in yield of clover were obtained on all soils studied. The data in Tables 6, 7 and 8 show that the uptake of magnesium, phosphorus and sulphur were also increased when calcium sulphate was used with dolomitic limestone. On nine Coastal Plain soils listed in Table 5, clover yields were increased approximately 60 per cent when calcium sulphate was added. Chemical analysis of plant tissue indicates that magnesium and phosphorus uptake were increased 95 and 62 per cent respectively from the addition of calcium sulphate (Figure 3). This indicates that sulphur present in calcium sulphate increased the availability of magnesium from dolomitic limestone and, directly or indirectly, effected an increase in the uptake of phosphorus.

On Ruston sandy loam and Eustis loamy fine sand (soils 6 and 7) listed in Table 5, the yields resulting from treatments that contained either magnesium nitrate or calcium sulphate with oyster shells were not significantly different. However, these treatments produced higher yields of clover than the treatments which did not contain magnesium or sulphur. Significantly higher yields of clover were obtained from applications of sulphate of potash-magnesia. When oyster shells served as the liming material, significantly higher yields of clover were obtained from treatments containing sulphur on Ruston sandy loam, Luverne fine sandy loam, Ruston fine sandy loam, Lakeland fine sand and Ruston sandy loam (soils 8, 9, 10, 11 and 12). Further increases in yield of clover were obtained when both magnesium and sulphur were included in the fertilizer treatments.

TABLE 7.—Effects of liming materials, magnesium and sulphur on phosphorus uptake by Ladino and Tensas red clover grown on nine Coastal Plain soils

Treatments*	Ruston** sl (6)	Eustis lfs (7)	Ruston sl (8)	Luverne fsl (9)	Ruston fsl (10)	Lakeland fs (11)	Ruston sl (12)	Orange-burg sl (13)	Kirvin fsl (14)
	Phosphorus uptake, mg. per pot								
Oyster shells	65	124	82	57	54	40	47	60	57
Oyster shells + Mg and S***	74	151	131	86	107	133	106	123	103
Oyster shells + $MgNO_3$	75	135	84	59	57	41	49	63	60
Oyster shells + $CaSO_4$	69	135	122	84	101	114	98	120	106
Dolomitic Limestone	70	142	107	60	52	37	47	50	53
Dolomitic Limestone + $CaSO_4$	76	153	141	85	104	134	105	110	102

*All treatments received the equivalent of 36 pounds of nitrogen, 144 pounds of P_2O_5 and 144 pounds of K_2O per acre.

**Ladino clover grown on soil No. 6, red clover grown on soils Nos. 7 through 14.

***Magnesium and sulphur applied as sulphate of potash-magnesia (Sul-Po-Mag) containing 18.5 per cent MgO, 21.5 per cent K_2O and 22.7 per cent S.

TABLE 8.—Effects of liming materials, magnesium and sulphur on sulphur uptake by Ladino and Tensas red clover grown on nine Coastal Plain soils

Treatments*	Ruston** sl (6)	Eustis lfs (7)	Ruston sl (8)	Luverne fsl (9)	Ruston fsl (10)	Lakeland fs (11)	Ruston sl (12)	Orange-burg sl (13)	Kirvin fsl (14)
	Sulphur uptake, mg. per acre								
Oyster shells	31	43	26	25	23	12	20	22	27
Oyster shells + Mg and S***	52	74	48	54	60	78	67	64	70
Oyster shells + $MgNO_3$	34	40	24	21	23	15	15	23	26
Oyster shells + $CaSO_4$	48	73	54	51	56	69	65	61	69
Dolomitic Limestone	34	40	30	25	22	11	16	14	26
Dolomitic Limestone + $CaSO_4$	50	73	58	51	65	74	63	67	66

*All treatments received the equivalent of 36 pounds of nitrogen, 144 pounds of P_2O_5 and 144 pounds of K_2O per acre.

**Ladino clover grown on soil No. 6, red clover grown on soils Nos. 7 through 14.

***Magnesium and sulphur applied as sulphate of potash-magnesia (Sul-Po-Mag) containing 18.5 per cent MgO, and 21.5 per cent K_2O and 22.7 per cent S.

On Orangeburg sandy loam and Kirvin fine sandy loam, significant increases in clover yields were obtained from the treatments containing sulphur. There were no differences in yield between treatments containing calcium sulphate and those containing sulphate of potash-magnesia. Clover responded to sulphur but failed to exhibit a significant response to magnesium on Orangeburg sandy loam and Kirvin fine sandy loam.

The data presented in Figure 4 represent a summary of yield and nutrient uptake of clover grown on Ruston sl, (soils 6, 8, and 12), Eustis lfs (soil 7), Luverne fsl (soil 9), Ruston fsl (soil 10), and Lakeland fs (soil 11).

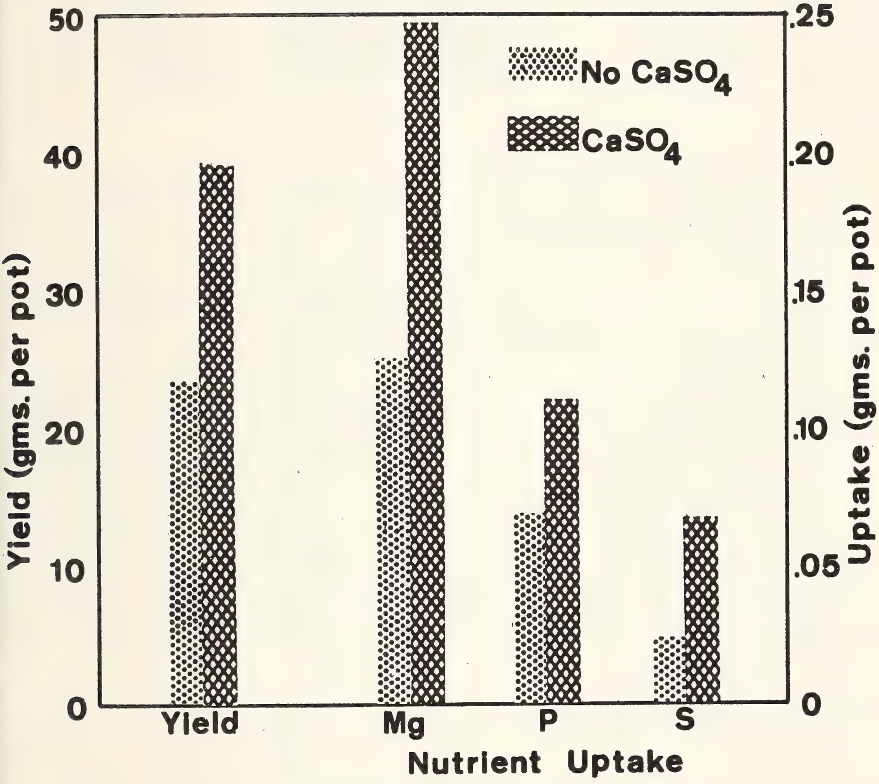

FIGURE 3.—Effects of calcium sulphate and dolomitic limestone on yield of clover and plant nutrient uptake (Nine soils listed in Table 5).

The addition of soluble magnesium as magnesium nitrate failed to significantly increase clover yields. Data on plant composition indicated larger amounts of magnesium were present in the plant tissue when this soluble source was used, but the uptake of phosphorus was not influenced to a noticeable degree by the magnesium treatment. Additions of sulphur as calcium sulphate had a marked effect on both

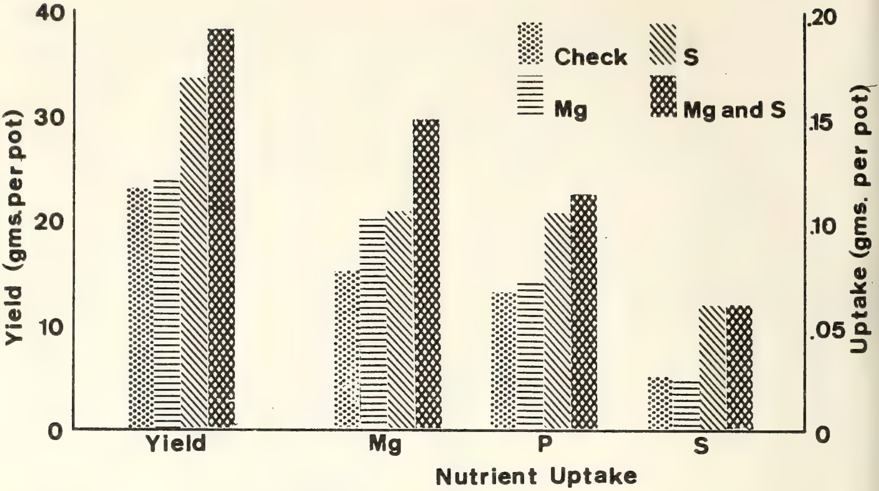

FIGURE 4—Effects of magnesium and sulphur additions on yield of clover and plant nutrient uptake when oyster shells were used as the liming material. (Soils 6 through 12 listed in Table 5).

yield and chemical composition of the clover. A highly significant increase, amounting to 52.1 per cent in growth, was obtained when calcium sulphate was applied.

Clover growing on soils that received calcium sulphate absorbed considerably more magnesium, phosphorus, and sulphur than did clover growing on the untreated soil. The amount of magnesium and phosphorus absorbed was increased 38.2 and 54.0 per cent respectively. This indicates that sulphur had an effect in increasing the availability and subsequent absorption of native soil magnesium. The data also indicates that sulphur had a favorable influence on increasing the absorption of phosphorus. The highest yield shown in Figure 4 occurred on soils receiving both magnesium and sulphur supplied as sulphate of potash-magnesia.

Response to Magnesium

Yield response, resulting from the combined application of a soluble source of magnesium and sulphur in comparison with the addition of sulphur alone, was attributed to magnesium. Yield data presented in Tables 2 and 5, coupled with chemical soil properties included in Table 1, indicate that yield response to magnesium was obtained on soils in which magnesium represented less than 10 per cent of the total cation exchange capacity and contained less than 55 ppm. of extractable magnesium. The yield response of clover, however, was influenced by the presence of sulphur in the fertilizer. Responses of clover to magnesium were not obtained on Orangeburg sandy loam and Kirvin fine sandy loam. These two soils contained 60 and 55 ppm. of extractable magnesium respectively, and 10 per cent of the exchange capacity was represented by magnesium.

An increase in yield of Ladino clover due to the application of magnesium was obtained on Ruston sandy loam (soil 6). This soil contained 52 ppm. of extractable magnesium, and 6.7 per cent of the exchange capacity was represented by magnesium.

The results of these greenhouse experiments indicate that on the sandy soils of the Coastal Plain areas of Louisiana a response of clover to magnesium could be expected if the amount of extractable or "available" magnesium is less than 55 ppm. and if magnesium represents less than 10 per cent of the total cation exchange capacity. The yield response of clover to supplementary magnesium is governed in part by the per cent magnesium saturation of the cation exchange complex of the soil and the presence of sulphates in the fertilizer used.

Summary and Conclusions

A greenhouse study was conducted to determine the effects of sources of liming materials, magnesium, and sulphur on the growth of Ladino clover and Tensas red clover. Soils from the Coastal Plain areas of Louisiana were used in this study.

Significant responses to magnesium and increases in magnesium and phosphorus uptake by clover were associated with the presence of sulphur in the fertilizer treatments. Yield responses were attributed to sulphur contained in ordinary superphosphate and sulphur supplied by sulphate of potash-magnesia. The results indicate that the response of clover to magnesium was conditioned by the presence of sulphur in the fertilizer.

Significant increases in yield of clover were obtained when sulphur as calcium sulphate was used with dolomitic limestone. The uptake of magnesium, phosphorus, and sulphur was also increased when calcium sulphate was used with dolomitic limestone. Sulphur in calcium sulphate increased the availability of magnesium from dolomitic limestone and effected an increase in the uptake of phosphorus.

Applications of sulphur as calcium sulphate significantly increased the yield of clover when oyster shells were used. Increases in the uptake of magnesium and phosphorus were also obtained when calcium sulphate was used with oyster shells. This indicates that sulphur had an effect in increasing the availability and subsequent absorption of native soil magnesium. The highest yield of clover occurred on soils receiving both magnesium and sulphur supplied as sulphate of potash-magnesia. The additional yield increase from the combined application of soluble magnesium and sulphur in comparison with the addition of sulphur alone was attributed to magnesium.

The results of these greenhouse experiments indicate that, on the sandy soils of the Coastal Plain areas of Louisiana, response of Ladino and Tensas red clovers to magnesium could be expected if the amount of dilute acid extractable or exchangeable magnesium was less than 55 ppm. or if magnesium represents less than 10 per cent of the total cation exchange capacity of the soil.

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Rice Bran In Beef Cattle Fattening Rations

T. WAYNE WHITE

Louisiana State University and
Agricultural and Mechanical College
Agricultural Experiment Station
Doyle Chambers, Director

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Rice Bran in Beef Cattle Fattening Rations

T. Wayne White

Rice bran, a by-product of rice milling, represents approximately 8 per cent by weight of the unmilled rice. Since the feed grain supply is somewhat limited in Southwest Louisiana, the extent that rice bran can replace grain in beef cattle fattening rations is of major concern to cattle feeders.

Literature Review

Craig and Marshall (1904) reported that rice bran increased gains in two of three experiments where it replaced less than 40% of the cottonseed meal in a cottonseed meal-cottonseed hull ration. However, Burns (1915) reported that average daily gains were decreased from 2.44 to 2.27 pounds when corn silage and cottonseed meal rations contained approximately 40% ground milo heads or 33% rice bran, respectively. The rice bran became unpalatable in warm weather because of rancidity. Similarly, Quesenberry (1929) found that steers fed only rice bran gained significantly less than when they were fed cottonseed meal; cottonseed meal and molasses; rice polish or brewers rice as supplements to corn silage. In contrast to these reports, Knox *et al.* (1933) reported increased gains and feed efficiencies when 30% rice bran replaced an equal amount of milo in steer rations.

More recently, Snell *et al.* (1945) conducted a series of experiments in which rations contained 60% corn; 30% rice bran and 30% rice polish; or 60% rice bran. Average daily gains and feed efficiencies were 2.37:7.8; 1.91:9.9, and 1.84:10.3 pounds on these respective rations. In other experiments in which basic corn rations contained 0, 14% rice bran, or 14% rice bran plus 14% molasses, the average daily gains and feed efficiencies were 2.30:8.0; 2.16:8.9, and 2.37:8.4 pounds for the respective rations.

Dvorachek (1926) reported that dairy cows produced 7% more milk and 5% more butterfat when they received a 29% rice bran concentrate than when they received a 29% wheat bran concentrate. Lush and Hale (1927) found that 4 pounds of rice bran could replace 3 pounds of milo and make up 36% of dairy rations without decreasing milk yield. Rice bran was unpalatable at this level if other feed was abundant. Tillman *et al.* (1951) reported similar gains when 0, 15, or 30% rice bran was added to basic corn rations for fattening swine. However, more feed was required to produce a pound of gain when 30% rice bran was fed.

Experimental Procedure

The rice bran used in these experiments was produced by local rice mills and had an average composition of 12.6% crude protein, 15.4% ether extract, 11.4% crude fiber, 7.6% water, and 12.8% ash. It contained 0.41% calcium, 1.45% phosphorus, and 0.97% magnesium. The hay and oats fed in these experiments were produced on the Rice Experiment Station, while the other ration ingredients were purchased through feed dealers from out-of-state sources. This series of five experiments was initiated in 1958 and completed in 1964.

The cattle (steers and heifers) were purchased from Southwest Louisiana sources. They were vaccinated against anthrax and blackleg, treated for internal and external parasites, and dehorned prior to each trial. All cattle were fed in concrete pens. Within each trial, the cattle were equally assigned to each rice bran level on the basis of sex, weight, and condition. Beginning and final weights were taken after a 15-hour period without feed and water. Since the trials were conducted with different breeds and rations for different lengths of time, each one will be discussed separately and then jointly.

Trial 1.—The ingredients and analysis of the concentrate portion of the four rations are shown in Table 1. The concentrate portion contained 0, 10, 20, and 30% rice bran which replaced an almost equal amount of grain sorghum. The soybean meal was slightly adjusted to maintain approximately isonitrogenous rations. The cattle were hand-fed the concentrate mixture twice daily and received poor quality lespedeza-grass hay free-choice. Twelve Hereford steers and 12 Hereford heifers were fed each ration in lots of 3 during this 87-day trial. The cattle were sold at auction when the trial was completed.

Trial 2.—The ingredients and analysis of the concentrate portion of the five rations are shown in Table 2. This 5 x 2 factorial experiment

TABLE 1.—Trial 1, Per Cent Composition and Analysis of the Concentrate Fed from January 6 to April 3, 1958

Ration No.	1	2	3	4
Rice bran[1]	0	10.0	20.0	30.0
Grain sorghum	82.9	72.8	62.7	52.6
Molasses	10.0	10.0	10.0	10.0
44% soybean meal	3.6	3.7	3.8	3.9
Urea	1.0	1.0	1.0	1.0
Minerals	2.5	2.5	2.5	2.5
Per cent crude protein	13.6	14.3	14.1	14.3
Per cent fat	2.4	2.6	2.6	5.8
Per cent crude fiber	2.9	2.7	3.3	4.2

[1] The per cent rice bran in the total ration was decreased to approximately 0, 7, 14, and 21% by feeding hay free-choice.

TABLE 2.—Trial 2, Per Cent Composition and Analysis of the Concentrate[1] and Roughage Fed from October 15, 1959, to March 23, 1960

Ration No.	5	6	7	8	9
Rice bran[2]	0	10.0	20.0	30.0	40.0
Corn	63.0	53.0	44.3	34.2	24.9
Cottonseed meal	16.0	16.0	14.7	14.8	14.1
Oats	10.0	10.0	10.0	10.0	10.0
Molasses	10.0	10.0	10.0	10.0	10.0
Salt	1.0	1.0	1.0	1.0	1.0
Per cent crude protein	12.2	12.5	12.8	12.4	13.5
Per cent fat	2.8	3.5	5.0	5.7	8.2
Per cent ash	4.2	4.3	5.7	7.1	8.4

[1] Lespedeza-grass hay contained 6.6% crude protein, 34.1% crude fiber; rice straw contained 3.9% crude protein and 28.0% crude fiber.

[2] The per cent rice bran in the total ration was decreased to approximately 0, 8, 14, 21, and 31% by feeding hay or straw free-choice.

compared 0, 10, 20, 30, and 40% rice bran in the concentrate and poor quality lespedeza-grass hay and rice straw as roughage. This provided 10 treatments, to each of which were assigned 6 Angus steers. The concentrate mixture was hand-fed twice daily while the roughage was fed free-choice. The steers were fed in lots of 3 for 160 days. At the end of the trial, the steers were sold for slaughter.

Trial 3.—The composition and analysis of the completely ground and mixed rations are presented in Table 3. These rations compared 30 and 50% rice bran. In contrast to Trials 1 and 2, the roughage (rice straw) was ground, mixed with the concentrate, and the complete rations fed free-choice.

Eighteen Hereford x Brahman steers and 6 Shorthorn heifers were assigned to each ration. They were fed in lots of 3 as in the previous trials. Similar groups of cattle were grazed on Gulf ryegrass with and without ground grain sorghum containing 10% molasses. At the end of the 92-day trial, the steers were sold at auction. Prior to this trial

TABLE 3.—Trial 3, Per Cent Composition and Analysis of Rations Fed from February 1 to May 3, 1962

Ration No.	10	11
Rice bran	30.0	50.0
Grain sorghum	29.4	9.4
Cottonseed meal	8.6	8.6
Molasses	10.0	10.0
Minerals	2.0	2.0
Rice straw	20.0	20.0
Per cent crude protein	12.2	12.9
Per cent fat	5.9	8.5
Per cent crude fiber	11.4	12.6
Per cent calcium	0.69	0.51
Per cent phosphorus	0.90	1.10

these cattle were on a wintering test for 67 days, gaining approximately 0.7 pound per head daily.

Trial 4.—The composition and analysis of the completely ground and mixed rations are presented in Table 4. These rations, which compared 30 and 40% rice bran, were fed free-choice. Thirty-two Hereford x Brahman steers were assigned to each ration and fed in lots of 4. Similar groups of cattle were grazed on Gulf ryegrass with and without ground grain sorghum containing 10% molasses. Eight of the steers assigned to each treatment had previously received a complete ration for 84 days and gained 2.2 pounds per head daily. Twenty-four of the steers were

TABLE 4.—Trial 4, Per Cent Composition and Analysis of Rations Fed from February 13 to May 14, 1963

Ration No.	12	13
Rice bran	30.0	40.0
Grain sorghum	29.3	19.3
Cottonseed meal	8.6	8.6
Molasses	10.0	10.0
Minerals	2.0	2.0
Rice straw	20.0	20.0
Vitamin A, terramycin mix[1]	0.1	0.1
Per cent crude protein	12.6	11.0
Per cent fat	7.2	8.3
Per cent fiber	10.9	12.0
Per cent calcium	0.49	0.51
Per cent phosphorus	1.35	1.75
Per cent magnesium	0.52	0.54

[1] Supplying 1,000 IU vitamin A and 7.5 mg. terramycin per pound of feed, supplied gratis Chas. Pfizer and Co., Inc., Terre Haute, Indiana.

TABLE 5.—Trial 5, Per Cent Composition and Analysis of Rations Fed from December 17, 1963, to May 21, 1964

Ration No.	14	15
Rice bran	20.0	30.0
Grain sorghum	38.0	28.0
Cottonseed meal	10.0	10.0
Molasses	10.0	10.0
Minerals	1.9	1.9
Rice straw	20.0	20.0
Vitamin A and terramycin mix[1]	0.1	0.1
Per cent crude protein	12.9	13.4
Per cent fat	5.0	7.5
Per cent fiber	10.2	10.6
Per cent calcium	0.40	0.52
Per cent phosphorus	0.90	0.90
Per cent magnesium	0.41	0.43

[1] Supplying 1,000 IU vitamin A and 7.5 mg. terramycin per pound of feed, supplied gratis Chas. Pfizer and Co., Inc., Terre Haute, Indiana.

previously on an 84-day wintering test and gained less than 0.4 pound per head daily. The steers were slaughtered and carcass information collected at the end of 90 days.

Trial 5.—The composition and analysis of the completely ground and mixed rations are presented in Table 5. A 2 x 4 factorial design was used to compare 20 and 30% rice bran rations fed free-choice after grazing ryegrass for 0, 52, 104, or 156 days of this 156-day trial. Therefore, the first group did not graze and the fourth group did not receive either complete ration. Sixteen Hereford steers were assigned to each of these grazing groups; eight of these were assigned to each ration at the end of their grazing period. The steers were slaughtered and carcass information collected at the end of the 156-day trial.

Results

Each trial will be discussed separately in the "Results" section and then jointly in the "Discussion" section.

Trial 1.—Average daily gain, feed intake, and feed efficiency data are presented in Table 6. Average daily gains were not significantly influenced by the level of rice bran. Steers outperformed heifers in most cases, but this was not unexpected as the steers also consumed more concentrate. The concentrate intake was almost equal for all rations.

TABLE 6.—Trial 1, Performance of Steers and Heifers Fed Four Levels of Rice Bran for 87 Days

Ration Per cent rice bran[1]	1 0	2 10	3 20	4 30
No. heifers	12	12	12	12
Initial wt. (lbs.)	437	431	437	454
Daily gain (lbs.)	1.73	1.87	1.79	1.92
Conc. intake (lbs.)	12.6	12.4	12.4	12.8
Hay intake (lbs.)	6.0	6.0	6.0	6.0
Feed/lb. gain (lbs.)	10.8	9.8	10.3	9.9
No. steers	12	12	12	12
Initial wt. (lbs.)	526	535	522	535
Daily gain (lbs.)	2.00	1.87	1.91	2.15
Conc. intake (lbs.)	14.4	13.8	14.0	14.2
Hay intake (lbs.)	6.0	6.0	6.0	6.0
Feed/lb. gain (lbs.)	10.2	10.6	10.5	9.4
Average — heifers and steers				
Daily gain (lbs.)	1.86	1.87	1.85	2.04
Conc. intake (lbs.)	13.5	13.1	13.2	13.5
Hay intake (lbs.)	6.0	6.0	6.0	6.0
Feed/lb. gain (lbs.)	10.5	10.2	10.4	9.6

[1] The per cent rice bran in the total ration was decreased to approximately 0, 7, 14, and 21% by feeding hay free-choice.

These cattle consumed an average of 6 pounds of lespedeza-grass hay per day, which made the total ration approximately 33% roughage. The hay lowered the rice bran level of the total rations to approximately 0, 7, 14, and 21%.

Trial 2.—The performance of Angus steers fed five levels of rice bran and two roughages is presented in Table 7. Varying the rice bran level in the concentrate from 0 to 40% did not significantly influence average daily gains. Steers receiving 3.5 pounds of lespedeza-grass hay produced significantly ($P < .05$) higher gains than those receiving 3.5 pounds of rice straw (2.09 vs. 1.96 pounds per day). Feeding 3.5 pounds of roughage (approximately 21% roughage rations) provided for approximately 0, 8, 14, 21, and 31% rice bran in the total rations. Feed intake, feed conversion, and dressing per cent were similar for all levels of rice bran and types of roughage fed.

Trial 3.—The performance data are presented in Table 8. Cattle receiving ration 10 (30% rice bran) gained (2.41 lbs.) significantly ($P < .01$) more than those (2.10 lbs.) receiving ration 11 (50% rice bran). Feed intake on these respective groups was 18.8 and 18.2 pounds per head daily, with corresponding feed conversions of 7.8 and 8.7.

TABLE 7.—Trial 2, Performance of Steers Fed Five Levels of Rice Bran and Two Roughages for 160 Days

Ration	5	6	7	8	9
Per cent rice bran[1]	0	10	20	30	40
	Lespedeza-grass hay				
No. steers	6	6	6	6	6
Initial wt. (lbs.)	447	375	428	389	437
Daily gain (lbs.)	2.12	2.10	2.11	1.98	2.16
Conc. intake (lbs.)	13.8	12.8	13.2	12.8	13.1
Hay intake (lbs.)	3.5	3.5	3.5	3.5	3.5
Feed/lb. gain (lbs.)	8.2	7.8	7.9	8.2	7.7
Dressing per cent	60.6	61.1	60.9	61.9	59.0
	Rice straw				
No. steers	6	6	6	6	6
Initial wt. (lbs.)	388	440	382	438	405
Daily gain (lbs.)	1.81	1.93	2.17	2.04	1.85
Conc. intake (lbs.)	12.3	13.3	12.8	13.1	12.4
Hay intake (lbs.)	3.5	3.5	3.5	3.5	3.5
Feed/lb. gain (lbs.)	8.7	8.7	7.5	8.1	8.6
Dressing per cent	60.5	60.2	60.6	60.4	60.1
	Average — lespedeza-grass hay and rice straw				
Daily gain (lbs.)	1.97	2.01	2.14	2.01	2.00
Conc. intake (lbs.)	13.1	13.1	13.0	13.0	12.8
Roughage intake (lbs.)	3.5	3.5	3.5	3.5	3.5
Feed/lb. gain (lbs.)	8.4	8.2	7.7	8.2	8.2
Dressing per cent	60.5	60.7	60.7	61.1	59.5

[1] The per cent rice bran in the total ration was decreased to approximately 0, 8, 14, 21, and 31% by feeding hay or straw free-choice.

TABLE 8.—Trial 3, Performance of Cattle Fattened on Rice Bran Rations, Pasture, or Pasture and Grain for 92 Days

Ration Per cent rice bran	10 30	11 50	Pasture	Pasture[1] and grain
No. animals	24	24	24	24
Initial wt. (lbs.)	430	430	422	418
Daily gain (lbs.)	2.41	2.10	2.05	2.27
Feed intake (lbs.)	18.8	18.2	—	6.4
Feed/lb. gain (lbs.)	7.8	8.7	—	—

[1] These grazing cattle had access to ground grain sorghum containing 10% molasses for one hour daily.

Almost 1 additional pound of feed was required to produce 1 pound of gain when ration 11 (50% rice bran) was fed. Diarrhea was prevalent at the higher rice bran level and explains the lower gains and less efficient utilization of ration 11. This suggests that 50% rice bran is too high. One steer on the latter ration died from urinary calculi.

The cattle that received grain in addition to grazing gained significantly ($P < .05$) more than those that only grazed ryegrass (2.27 vs. 2.05 lbs. per head daily). The average daily grain intake was 6.4 pounds. There was no significant difference in gains made by cattle receiving ration 10 and those receiving grain in addition to pasture or between those receiving ration 11 and those grazing pasture alone.

Trial 4.— Performance data are presented in Table 9. This trial is a duplication of Trial 3 except for a lower maximum level of rice bran. Ration 12 (30% rice bran) provided for significantly ($P < .01$) greater daily gains (2.55 lbs.) than ration 13 (40% rice bran). Both rations were superior ($P < .01$) in this respect to pasture or pasture plus grain. Feeding grain on pasture did not influence average daily gains. Average grain consumption was 3.5 pounds per day. Grain consumption was lower when the ryegrass was lush and abundant but increased toward the end of the trial as the grass diminished.

Carcass grades decreased significantly ($P < .01$) from ration 12 to ration 13 to pasture plus grain to pasture alone. A similar decrease in dressing per cent was noted from both rations to pasture plus grain to pasture alone. Steers that were wintered on roughage gained more but dressed and graded less on all treatments than those that were wintered on heavy feed. Urinary bladder stones were found in 15 steers fed ration 12, and in 13 steers fed ration 13. Several cases of diarrhea were observed but they were not as severe as in Trial 3.

Trial 5.—This trial was conducted to give specific information regarding the length of pasture-feedlot combinations not established in previous trials. The performance data are presented in Table 10. Average daily gains and carcass grades were not significantly different

TABLE 9.—Trial 4, Performance of Cattle Fattened on Rice Bran Rations, Pasture, or Pasture and Grain for 90 Days

Ration Per cent rice bran	12 30	13 40	Pasture	Pasture[1] and grain
	Wintered on roughage prior to test			
No. steers	24	24	24	24
Initial wt. (lbs.)	441	445	443	429
Daily gain (lbs.)	2.78	2.44	2.06	1.90
Carcass grade[2]	10.0	8.6	6.3	4.7
Dressing per cent	55.4	55.6	50.8	48.9
	Wintered on heavy feed prior to test			
No. steers	8	8	8	8
Initial wt. (lbs.)	570	590	603	616
Daily gain (lbs.)	1.88	1.79	1.36	1.24
Carcass grade[2]	10.3	10.0	8.4	7.6
Dressing per cent	59.0	58.4	55.3	52.8
	Average			
Daily gain (lbs.)	2.55	2.28	1.73	1.88
Carcass grade[2]	10.1	8.9	5.4	6.8
Dressing per cent	56.4	56.2	49.8	52.0
Feed intake (lbs.)	21.2	20.6	—	3.5
Feed/lb. gain (lbs.)	8.3	9.0	—	—

[1] These grazing cattle had access to ground grain sorghum containing 10% molasses for one hour daily.

[2] 7 = Standard, 8 = High Standard, 9 = Low Good, 10 = Good.

when steers were fed rations 14 or 15 (20 or 30% rice bran). Steers fed ration 14 dressed significantly higher than those fed ration 15.

As was expected, drylot feeding for 156 days provided for significantly ($P < .01$) higher average daily gains than any combination of grazing and feeding or grazing only. Feeding for any length of time significantly ($P < .01$) increased average daily gains, carcass grades, and dressing per cent when compared with grazing only. Average daily

TABLE 10.—Trial 5, Performance of Cattle Fattened on Rice Bran Rations and/or Pasture for Various Lengths of Time

Ration Per cent rice bran	14 20	15 30	14 20	15 30	14 20	15 30	Pasture
No. steers	8	8	8	8	8	8	16
Initial wt. (lbs.)	408	408	409	408	408	408	406
Days:							
Feed	156	156	104	104	52	52	0
Pasture	0	0	52	52	104	104	156
Overall daily gain (lbs.)	2.43	2.36	2.16	1.99	2.04	1.92	1.34
Daily gain on feed (lbs.)	2.43	2.36	2.81	2.55	2.71	2.60	—
Daily feed intake (lbs.)	20.4	19.8	21.4	22.9	23.2	22.7	—
Feed/lb. gain (drylot) (lbs.)	8.4	8.4	7.6	9.0	8.6	8.7	—
Carcass grade[1]	9.4	9.0	8.9	9.0	8.9	8.6	7.3
Dressing per cent	59.2	57.6	59.1	57.1	57.4	55.9	52.8

[1] 7 = Standard, 8 = High Standard, 9 = Low Good, 10 = Good.

gains and carcass grades were not significantly different when steers were grazed 52 or 104 days and fed the remainder of the 156-day test. The dressing per cent was lower for steers fed 52 days than for those fed 156 or 104 days ($P < .01$), ($P < .05$). The two latter groups did not differ significantly in dressing per cent or grade.

All carcasses were examined to determine the influence of ryegrass pasture on external fat color. Steers which received feed for 156, 104, or 52 days had normal fat color. Steers that were grazed only for 156 days had slight yellow to normal fat. Urinary bladder stones were found in 11 steers fed ration 14 and in 9 steers fed ration 15.

Discussion

While there are some differences between trials in feeding methods, roughages, ration ingredients, history of cattle, length of feeding period, breed, and sex, the data appear to agree quite well.

When considering Trials 1 and 2, it should be remembered that the concentrate was hand-fed daily and that the roughage was fed separately. The average roughage intake made up approximately 33 and 21% of the total rations in the respective trials. The roughage had an overall ration effect of decreasing the rice bran content to approximately 0, 7, 14, and 21% in Trial 1 and to 0, 8, 14, 21, and 31% in Trial 2. With these adjustments in rice bran levels, the data from these trials and others can be compared. Average daily gains were not significantly influenced by the levels of rice bran tested in either trial. The average concentrate consumption was similar at all rice bran levels and in both trials.

Comparing the average daily gains of cattle fed rations 9, 10, 12, and 15, (approximately 30% rice bran) in Trials 2, 3, 4, and 5, respectively, close agreement can be noted between rations 10, 12, and 15. Cattle were fed these rations free-choice and consumed more than those hand-fed ration 9. Also, cattle previously wintered on poor quality roughage and subsequently fed ration 10 were initially thinner than those fed ration 9. Cattle that were previously wintered on poor quality roughage and subsequently fed ration 12 were initially thinnest of all and gained more than any other group in drylot. Cattle that were fed ration 12 after wintering on a fattening ration gained less than any other group. Average daily gains were significantly ($P < .01$) higher when rations 10 and 20 (30% rice bran) were fed than when ration 11 (50% rice bran, Trial 3) or ration 13 (40% rice bran, Trial 4) was fed, respectively.

These results are in keeping with those reported by Craig and Marshall (1904), and Knox *et al.* (1933) with fattening cattle, Dvorachek (1926), and Lush and Hale (1927) with dairy cows, and Tillman *et al.* (1951) with fattening swine. Snell *et al.* (1945) found that 60% rice bran or a combination of 30% rice bran and 30% rice polish decreased steer gains. They further reported that the average daily gains were decreased from 2.30 to 2.16 pounds when 0 and 14% rice bran rations were compared. When 14% molasses was included in the latter ration, the average daily gain increased to 2.37 pounds.

There was no significant difference in average daily gains of rations 14 and 15 (20 and 30% rice bran, Trial 5) during the drylot feeding periods or during the 156-day grazing and feeding period.

Burns (1915) and Lush and Hale (1927) reported that rice bran was unpalatable because of rancidity. Palatability was not a problem in these experiments, as the cattle consumed the rations readily. The molasses may have masked any rancidity that occurred in these rations.

Feed conversion appeared to be somewhat variable between trials at similar rice bran levels. However, these differences were small. In Trials 1 and 2 feed efficiency may have been influenced by feeding roughage free-choice. Within each of Trials 3, 4, and 5, feed efficiency decreased slightly as the level of rice bran increased.

Dressing percentage data were obtained in Trials 2, 4, and 5. In Trials 2 and 4, the differences due to rice bran level were not significant. However, in Trial 5, steers fed ration 14 (20% rice bran) dressed significantly ($P < .01$) higher than those fed ration 15 (30% rice bran). Carcass grades decreased significantly ($P < .01$) from ration 12 (30% rice bran) to ration 13 (40% rice bran) in Trial 4, but this was not observed in Trial 5 where 10% less rice bran was fed.

The frequency of diarrhea increased as the level of rice bran increased but did not become a problem until 40% rice bran was fed. With 50% rice bran, scouring was quite frequent.

Urinary bladder stones were found in several steers. This indicates a need for more research into their cause and prevention. The high magnesium level of rice bran may be responsible for their occurrence, but stones have been reported in other sections of the United States when grain sorghum was fed.

The average daily gains of steers grazed on ryegrass in Trials 3 and 4 appear to be quite different. Average gains were less in Trial 4 than in Trial 3. This is considered to be the result of heavy feeding one-fourth of the steers in Trial 4 on another experiment prior to grazing. Steers which gained slowly while wintering on roughage gained similarly (2.05 pounds per head per day) in both trials.

Feeding 6.4 pounds of grain sorghum containing 10% molasses significantly ($P < .05$) increased average daily gains of grazing steers in Trial 3. In Trial 4 an average grain intake of 3.5 pounds did not influence gains regardless of prior feeding history. Carcass grades were increased in Trial 4 by feeding grain. Apparently, cattle in Trial 4 stayed at the grain trough during the day instead of grazing.

Cattle that grazed for 156 days in Trial 5 gained 1.34 pounds per head daily, compared with 2.05 and 1.73 pounds in Trials 3 and 4, respectively. This may be partially explained by the influence of prior wintering on subsequent gains. Steers in Trial 5 were not as thin as those roughed through the winter prior to Trials 3 and 4 but were thinner than those fed prior to Trial 4. Another possible explanation is the longer grazing period in Trial 5, which started 45 to 55 days earlier. Steers that grazed 52 days gained 0.87 pound per head daily compared with 1.63 pounds gained by those that grazed 104 days. This suggests that grass was less abundant earlier.

Summary

The performance of cattle fattened on various levels of rice bran is compared in 5 trials with 15 rations. Within trials, average daily gains and carcass grades were not influenced by including up to 30% rice bran in the total ration. Increasing the rice bran level to 40 or 50% decreased average daily gains, carcass grades, and feed efficiencies. Differences between trials are discussed. The incidence of diarrhea increased as the rice bran level increased above 30%. Urinary bladder stones were found in several steers when they were slaughtered.

Cattle grazed on ryegrass made satisfactory gains. Differences between trials are explained on the basis of previous feeding history. Drylot feeding for 156 days produced higher gains than grazing and feeding for 156 days. Gains and carcass grades were not significantly different when steers were grazed for 52 or 104 days and fed for the remainder of the 156-day test.

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